COAL HANDLING SYSTEM-ITS PERFORMANCE MONITORING & SUGGESTIVE MEASURES FOR IMPROVEMENTS

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CERTIFICATE

This is to certify that the thesis entitled **“Coal Handling System- Its Performance Monitoring & Suggestive Measures for Improvement”** being submitted by **Somanath Ojha** for the award of the degree of Master of Technology (Research) of NIT Rourkela, is a record of bonafide research work carried out by him under our supervision and guidance. He has worked for two years on the above problem at National Institute of Technology, Rourkela and this has reached the standard fulfilling the requirements and the regulation relating to the degree. The contents of this thesis, in full or part, have not been submitted to any other university or institution for the award of any degree or diploma.

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Abstract

The coal handling process involves a number of activities from loading and unloading to stockpile. This procedure can be carried out by coal conveying system which includes a large number of mechanical equipment. The important activities under coal handling include loading/unloading, dumping, transporting etc. which are done with the help of various mechanical equipment. Every organization wants to profit as much as possible and increases their production rate by using maximum effort for care and maintain. And it is possible if the equipment is running in good condition with zero breakdowns, zero accident, and zero wastage. This research work presents a practical analysis for monitoring the operational performance of equipment, which shows the two additional objectives: the first one is the identification of major causes of production losses which are born from malfunctions, breakdowns, and bad operating programme. And the second one is the implementation of a suitable and appropriate methodology for improvement of coal handling systems, which handling the coal from bunker to stockyard within an industry. The data are analyzed and compared with World class to Obtained OEE. During the operation, many reasons are there, which affect the production rate called six big losses. To minimize the six big losses and improve productivity, an accurate effective estimation of equipment is necessary and offers a suitable methodology.

For the purpose of the study, a case study methodology is applied in order to analyze in the depth of maintenance in a real context. The primary focus of this research work is to monitor the equipment performance in coal handling plants and its contribution to the company for overall operation. The OEE data are recorded through tables and compared to world class OEE considering the operational losses and also performance reports are briefly analyzed through figures in terms of equipment failures in different locations, idle time for materials, operators and speed loss time for minor stoppages like sensor blocked, cleaning/checking or component jamming. For minimizing the downtime and promote productivity, a suitable methodology is developed through tables for determining the status of coal handling equipment viz. Tippler, Side arm charger, Reversible apron feeder, Belt conveyor system, Stacker, Reclaimer.

This research work deals with the quantitative measurement of equipment performance in coal handling plant, which defines losses for many reasons. As a result, valuable information is provided concerning the performance monitoring of production equipment and implementing a suitable methodology for improvement

of coal handling machinery operations viz tippler, side arm charger, reversible apron feeder, belt conveyor, stacker, reclaimer.

Introduce the estimation and evaluation of OEE procedure which is highly valid and accurate performance indicator and has become very popular in all the industries starting from mining area for excavation of material to harbour area for material handling. OEE shows a right metrics to analyze the ordinary issue and improving the whole process. There are many formulas, systems and metrics being used to improve the whole production process, but one and only OEE reduces complex problem into easy. The biggest advantage of OEE allows companies to have separate business functions by applying a single easy to understand the formula. OEE is by far the most effective benchmarking tool in making sound management and maintenance decisions.

The dissertation concludes with a summary of the contribution and the scope of further work.

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Chapter 1

INTRODUCTION

1.1 Overview

Coal handling plant is a plant which handles the coal from its receipts from coal mines to transporting it to the boiler for generating the power, coke oven for making coke and store in the bunker. Coal handling refers to the movement and storage of coal from the time it arrives at the plant. As consumption of coal is very large, the design and layout of coal are in simple but robust with a view to reducing maintenance and running cost to the lowest possible consistent to reliability.

1.2 Delivery to the Plant

Before methods of coal delivery are discussed, note that all incoming coal should be weighed. This practice allows the plant to check contractor weigh-bills and may help personnel in spotting coal quality problems. For example, if a load is heavier than expected, there may be excess moisture or perhaps a high percentage of fines in the load.

Coal is delivered to the plant by truck, railroad, or barge. Even though truck and railroad deliveries are most common, each plant should choose the most economical method compatible with timely delivery and the plant's unloading equipment. Only experienced and qualified personnel who are familiar with facility unloading practices and procedures should be given the responsibility of receiving coal. All training and certification should be kept up to date, and clear procedures should be made available to all personnel responsible for unloading coal.

1.2.1 Transportation

1.2.1.1 Truck

Truck delivery offers several advantages over other forms of coal transport. For instance, trucks can use roads whereas railroads and barges are limited to tracks and waterways. This makes truck transportation faster and more accessible in most situations. Truck delivery is best suited for delivery ranges of 8 to 640 km for a plant that consumes between 25 and 200,000 tons of coal per year. A single truck can hold approximately 30 tons. For this transport range, delivery time varies from 1 to 10 hours including loading and unloading. Because most trucks are equipped with hydraulic dump beds, it is easy to unload coal onto the ground or into underground hoppers. Trucks should be unloaded on solid, level ground that is clear of power lines and overhead equipment.

1.2.1.2 Railroad

Railroad transport is economical for distances of 16 to 3200 km, especially when rail service is available directly from the mine (or preparation facility) to the plant. Railroads best serve plants that consume from 50 to 4 million tons of coal per year. One railcar can hold around 100 tons. Delivery can take anywhere from a day to a month, including loading and unloading time. When the coal arrives at the plant, there are several methods for unloading railcars. The most common method is "gravity discharge." Some plants use a crane, but a crane is undesirable because it increases breakage and encourages segregation of the coal.

"Gravity discharge" can be done two ways. Coal can flow out the bottom of the railcar or it can be dumped by overturning the entire railcar. Cars emptied from the bottom can be discharged at ground level into an underground hopper or from the top in case of BOXN wagon into a pile, hopper.

A rotary car dumper is valuable for a plant where large quantities of coal must be unloaded quickly. Rotary car dumpers are economical when significant demurrage charges (fines paid by the plant for holding a freight car beyond its scheduled departure time) result from a slow turnaround of railcars.

1.2.1.3 Barge

River barge delivery is practical for distances of 16 to 1600 miles, especially when water transportation is near both the mine (or preparation facility) and the thermal power plant. Barge transportation is best for plants that consume more than 50,000 tons of coal per year. One barge can carry anywhere from 600 to 3000 tons. Delivery can take anywhere from a day to a month. At the plant, barges are unloaded by a bucket elevator system or by crane. Sometimes barges even carry their own crane.

1.2.1.4 Ropeways

This mode of coal transportation is used where coal mines are located near the power stations. Coal is brought by hanging bucket/trolleys traveling on track ropes, which are pulled by a haulage rope with a driving mechanism. The payload of each bucket varies from 1 to 3 tons. Automatic loading and unloading mechanisms are provided at loading and unloading stations. The rate of unloading varies from 75 to 275 MT/Hr depending on the type of ropeways used. This type of coal transportation is very economical compared to road or rail transportation. The only disadvantage of this system is a long time for maintenance works.

1.2.1.5 Other Methods

Coal can be transported by conveyors to the plant. However, this technique is not practical unless the plant is within a few miles of the mine (or preparation facility). Also, coal can be transported by suspending it in water and pumping it through a pipeline (called a slurry flow pipeline). Once at the plant, this coal must be dried. The use of such pipelines is rare and primarily experimental.

1.2.2 Scheduling

In most cases, a plant receives coal as it is needed for normal operations. Although there may be certain situations when the plant must replenish its long-term storage, a plant should have a routine delivery schedule. Some exceptions arise in areas where winter delivery is uneconomical or impossible. For these installations, a plant must receive its annual supply of coal over the summer. By scheduling these deliveries to match a plant's unloading capacity, the installation can reduce the possibility of demurrage charges.

1.3 Storage

1.3.1 Short-Term

Short-term storage provides coal for day-to-day heating plant operations. A military plant should carry anywhere from a few days to several weeks' worth of coal in short- term storage. Short-term storage is classified as either "active" (live) or "inactive" (dead). Live storage refers to coal that can be fed directly into the furnace without being transferred through other storage areas. The coal can be fed by chute, conveyor, or tractor. Dead storage refers to coal that must pass through another storage area before it can be fed to the furnace. Dead storage is transferred to live storage areas by conveyor, tractor, or both. If dead storage is located far from the plant, it may be necessary to transfer the coal to the plant using train cars or trucks. For these cases, just-in-time delivery is especially attractive.

1.3.2 Long-Term

Long-term storage is dead storage that holds coal for emergencies or for those rare instances when the plant has exhausted its short-term supply. A military plant should carry a 90-day supply of coal in long-term storage.

1.3.3 Devices

There are many ways to store coal; each method has its advantages and drawbacks. The most expensive methods provide the best coal protection and allow for the simplest and cheapest recovery while less expensive methods provide much less protection and require more costly, less convenient recovery. In addition, enclossd storage reduces air and water pollution while making the plant site look cleaner.

1.3.3.1 Bunkers

Bunkers provide live storage. They are usually situated above the plant floor so that coal can be fed directly to the furnace by the chute. To accommodate unloading, bunkers have sloped bottoms to funnel the flow of coal.

1.3.3.2 Silos

Silos provide both live and dead storage. Live storage is maintained on a "live shelf located midway up the silo. This shelf is sloped towards an outlet on the side of the silo. When the live shelf is filled, excess coal becomes dead storage and spills over onto a lower shelf. Coal in dead storage can be reclaimed by a conveyor and returned to the live shelf. The shelves should be inclined at least 55 degrees above the horizontal to facilitate the flow of coal.

Silos provide excellent protection because they are completely enclossd. They shield against the weather and limit air circulation through the coal. In addition, silos are convenient and economical to unload. Unfortunately, these benefits are frequently offset by their large initial cost.

1.3.3.3 Sheds

A shed is a roofed building that protects live or dead storage from the weather. It can hold much more coal than a silo and is less expensive to build. However, it cannot offer the same protection or convenience of a silo. For example, a shed does not adequately limit air flow through loose coal. Therefore, coal maintained in a shed as long-term dead storage must be compacted. This compaction is difficult to achieve near posts and walls where non-compacted coal can act as a chimney for spontaneous combustion. In addition, compacting becomes difficult when the shed is nearly full. In terms of convenience, sheds are less efficient to unload because coal must be carried by tractor to a conveyor or hopper.

1.3.3.4 Outside Bins

An outside bin is a roofless, three-sided structure that can hold live or dead storage. Besides offering some protection from wind erosion, it serves primarily as a retainer for a coal pile. Because of its many similarities to the coal pile, handling and maintenance techniques for both storage methods are the same. However, the outside bin presents a drawback over the open pile because it is difficult to compact the coal along the bin walls.

1.3.3.5 Piles

A coal pile is generally used for long-term storage. It offers the least protection of all the storage methods; however, it requires the least capital investment. Due to the military requirement to keep 90 days of coal on hand, a coal pile is frequently the most economical means of storing this much coal.

The coal pile should be built on a paved surface. However, if concrete or asphalt is not available, the base can be constructed of heavily compacted coal. Regardless of the material, the base must allow for proper drainage of the pile so the pile can be accessed during all weather conditions. In addition, proper drainage helps maintain coal quality as it helps the plant control water pollution.

1.4 Importance of Material Handling

The foremost importance of material handling is that it helps the productivity and them by increases profitability of an industry. A well-designed material handling system attempts to achieve the following:

- Improve efficiency of a production system by ensuring the right quantity of materials delivered at the right place at the right time most economically.
- Cut down indirect labour cost.
- Reduce damage of materials during storage and movement.
- Maximize space utilization by proper storage of materials and thereby reduce storage and handling the cost.
- Minimize accident during materials handling.
- Reduce overall cost by improving material handling.
- Improve customer services by supplying materials in a manner convenient for handling.
- Increase efficiency and saleability of plant and equipment with integral materials handling features.

1.5 Motivation

- Performance measurement is a key strategy for organizational improvement. Without monitoring the equipment, a company cannot increase their production rate. So, OEE is a valid and accurate method for calculating the efficiency of coal handling equipment.
- It analyzes and evaluate the results of plant production rate. It is also adopted to eliminate the major causes of poor performance.
- To improve the efficiency of the material handling process in an industrial environment and Inspection of industrial equipment to improve plant productivity.
- The primary focus is to design a method for finding out the root causes of the coal handling equipment.
- To track & trend the improvement or decline in equipment effectiveness over a period of time.

1.6 Broad Objective

The objective of the proposed work is to make study of system of coal handling and associated equipment explicitly and make suggestive measures for improvement of coal handling system of machinery like tippler, side arm charger positioning equipment to tippler, belt conveyor system, reversible apron feeder, stacker, reclaimer etc. under the backdrop of the aforementioned scenario the objectives of the present research work consists of the following.

- A brief review of equipment and its system of cyclic operation such as unloading, conveying, stacking, reclaiming.
- Collection and collation of field data for the losses of availability, performance and quality of the equipment yearly basis.
- Development and recommendation of appropriate methodology for monitoring the candidate machinery and suggestive measures for improvement of their availability and performance.

1.7 Methodology

The objectives are proposed to be achieved through well-designed steps. The methodology consists of following steps:

- **Literature Review:** The depth of literature review is carried out for investigating the performance monitoring of coal handling system and also understand the equipment like tippler for wagon unloading, side arm charger for positioning the wagon into tippler platform, reversible apron feeder for feeding the material to the belt, belt conveyor for carrying the material, stacker for stacking the material to the stockyard and reclaimer for reclaiming the material from stockyard.
- **Plant visit and data collection:** Data is collected from the plant documenting the losses of the each equipment in their downtime, speed and quality in terms of filling factor.
- **Introducing the Overall Equipment Effectiveness (OEE) for performance monitoring:** In this study, OEE is developed for monitoring the coal handling equipment like tippler, side arm charger, reversible apron feeder, belt conveyor, stacker, reclaimer and analyzing the losses of availability, performance, quality with a comparison to World class OEE.
- **Suggesting the appropriate methodology for improvement:** In this study, an appropriate methodology is investigated for knowing the parameter, component and sensors/technology of equipment for the improvement of coal handling equipment.

1.8 Expected outcomes

- Increased productivity and OEE.
- Cost reduction up to a great extent.
- Reduce accident.
- A Higher confidence level among the employees.
- Keep the workplace level among the employee.
- The favorable change in the attitude of the operator.
- Working goals by working as a team.
- Horizontal deployment of a new concept in all the areas of the organization.

- The workers get the feeling of owning the machine.
- Associate empowerment.
- A safer workplace.
- An easier workload.
- Minimizing the Defects.
- Minimizing the Breakdowns.
- Minimizing the short stoppage.
- Minimizing the waste

1.9 Organization of the Thesis

The present *Chapter1* Introduction the subject of the topic its contextual relevance and the related matters including the objectives of the work and the methodology to be adopted are presented.

Chapter2 provides reviews on several diverse streams of literature on different issues of the topic such as LED indicating device for level and volume of coal in bunker, PLC Microcontroller for temperature monitoring, PLC and SCADA for fault detecting and monitoring, wire brush system for removing the sticky material, failure reduction, diagnosis the cause of damage and implementation of six sigma, QC tools and TPM with their technique and also many more are presented in this chapter.

Chapter 3 discusses the coal handling equipment like tippler for wagon unloading, side arm charger for positioning the wagon into tippler platform, reversible apron feeder for feeding the material to the belt, belt conveyor for carrying the material, stacker for stacking the material to the stockyard and reclaimer for reclaiming the material from stockyard are explained.

Chapter 4 derives briefly about the OEE & six big losses with practical examples and its data analysis for performance monitoring of coal handling system are discussed. It is also compared with World class to Obtained OEE.

Chapter 5 Suggests a suitable appropriate methodology for monitoring the plant equipment. It also includes the result and discussion of coal handling equipment for comparison of OEE its factor and breakdown hour before & after improvement are discussed.

Chapter 6 presents the case study application of coal handling machinery for simulation of breakdown data analysis. This chapter concludes the different equipment falls under definite random number distribution range.

Chapter 7 presents the summary of the results, recommendations and scope for future work in the direction of studies on organizational improvement performance. This chapter concludes the work covered in the thesis with implications of the findings and general discussions on the area of research.

1.10 Summary

In this chapter, the general overview of coal handling plant is presented. The delivery of coal to the plant via truck, railroads, barges, ropeways and other methods are also discussed. It also emphasizes the storage of coal in terms of long term basis and short-term basis by bunkers, silos, sheds and piles. It indicates the important of material handling while handling the material within the plant.

Chapter 2

REVIEW OF LITERATURE

2.1 Overview

The objective of coal handling plant (CHP) is to supply the processed coal to coal yard and to stack the coal to coal stockpile area. Coal is a hard black or dark brown sedimentary rock formed by the decomposition of plant material, widely used for production of metallurgical coke, tar, chemicals such as ammonia and urea used in fertilizer plant, coal gasification can be used to produce syngas for transportation fuel such as gasoline and diesel, as a fuel for generating electricity by thermal power plant. The importance and magnitude of the business of coal handling are emphasized by the fact that raw material transporting from the collieries by the various methods by rail, road, and aerial ropeway or conveyor belt. After transporting the coal from coal mines to the power station, coal is required to be stored in the storage yard or to be fed to the boilers and this is accomplished with the help of a system of equipment called coal handling plant. When coal transportation system fails it is essential that coal should be made available in the stock yard so that there may not be a stoppage of power generator plant. To meet such situation, it is necessary that sufficient stock of coal is made at the power station so that there may not be an interruption in coal supply at the end-user location. It is expected to keep a minimum ground stock of coal to cater to the requirement of the station such period. Thus besides unloading the coal received by various mode of transportation, coal handling plant has to perform two main functions (i) stacking and reclaiming of coal to respective uses in case direct supply from mines fails (ii) to store the bunker with the coal directly received from mines. The continuity of production is possible only when the availability and utilization of equipment are exercised. Although the coal handling equipment is enough rugged, the conditions under which this equipment are used are quite difficult to keep them workable. Failure of the equipment become quite frequent as the age of the equipment grows. Therefore, it is essential to monitor the performance of the coal handling equipment and take appropriate measures to improve the availability as well as the utilization of such machinery.

2.2 Literature Survey

Bob, B. et al. (1988) proposed a reliable electrical heater in the winter season to avoid the shut down in CHP. The proposed electric heating module is used for melting the ice bond efficiently and eliminates plugging caused by freeze-ups.[3]

Mukhopadhyay, A. K. et al. (1996) proposed for research in Condition Monitoring and Performance Analysis of a Vibrating Screen. In this paper, authors are presented sensors and monitors are being used for monitoring vibrating screens in condition based approach and Performance Analysis.[2]

Maiti, J. et al. (2004) proposed Lean Maintenance – Concept, Procedure, and Usefulness. In this paper, authors are presented a systematic approach for eliminating the waste which are excess production, excess processing, delays, transportation, inventory and defect through continuous improvement. The authors also enclossd the benefit of lean maintenance are reduce work in progress, increased capacity, improved customer satisfaction, increased inventory turns and reduction of cycle time.[22]

L, Simmon.et al. (2008) proposed an algorithm enabling the conveyor belt to dynamically adjust its speed for RIFD reader to reliably identify tags without prior knowledge. Operational scheduling of the coal handling is an NP-hard in nature.[15]

Ozdeniz, A. H. et al. (2008) proposed effective parameters in the coal stockpile are time, weather, temperature, atmospheric pressure, air humidity, velocity and direction of wind are measured by means of a computer-aided measurement system to obtain input data for Artificial Neural Network (ANN) which is used here to estimate the coal stockpile behaviour under the above parameters.[20]

Laha, D. et al. (2009) Proposed the permutation flow shop scheduling problem with the objective of minimizing the makespan. In this paper, authors are presented a new hybrid heuristic, based on simulated annealing and an improvement heuristic. The heuristic is designed by combining elements from simulated annealing, NEH, and composite heuristics. It has shown the empirical results on multiple instances of problems of various sizes.[16]

Sinha, S. et al. (2009) proposed for Prediction of Failures at Surface Miners using Artificial Neural Network Modelling Approach. In order to define an optimum model, a series of analyzes are conducted to determine the optimum architecture of ANN using the trial and error method. In this paper, authors are presented ANN model for prediction of failures of surface miners. According to the adequate consistency observed between the predicted results obtained from the presented model and measured data, it is concluded that this approach is applicable to predict the failure of Surface Miners.[28]

Sokovic, M. et al. (2009) proposed basic quality tools for continuous improvement of an organization. In this paper authors are presented for systematic use of 7QC tools for all processes phase starting from beginning of product development to delivery of production management process and also describing the 7QC tools methods and techniques for involving in different phases for continuous improvement process like (PDCA-cycle consists of four consecutive steps; “In plan step- decision are taken for changing and improved process through some of the quality tools”, “In do step- implementation is going on for changing and improved”, “In check step- control and measurement process is carried on for checking the system is ok or not” “In act step- adaption or reaction of changes in PDCA cycle for Keeping improvement on-going”), Six Sigma (DMAIC- defining the problem, measures the problem in current status, analysis the problem through data to find out the causes, improving the solution through brainstorming in piloting basis, controlling the improved process with standardization and on-going monitoring) and Lean Six Sigma for eliminating waste and non-value adding action; lean means speed and quick action (reducing unneeded waiting time) in short-term change and six sigma means identifying the defects and eliminating them in long term change. In view of this, it is evident that continuous improvement can be possible with the help of quality tools, techniques and methods which are helpful the quality engineers for doing their own job in site.[30]

Zimroz, R. et al. (2009**)** proposed to improve the reliability of conveyor belt system by analyzing their failures, root causes and some minimal parameter for condition monitoring techniques. In this paper authors focuses the most frequent failures, types and the location of failures (damaged of belts due to pulley or idler faults, crack of shaft in gearboxes, pulleys, couplings is results of overloading due to increased turning resistance of idlers and pulleys) and their importance in the context of maintenance by condition monitoring techniques for different parameters in CBS i.e. vibration is monitored For gearboxes (geared wheel and bearings) and pulleys (bearings), speed is measured for rotating shaft and moving belt, some magnetic field sources are placed in joint area for detection of belt joints, electromagnetic field transmitter is used, if belt is cut, temperature measures for bearing condition and for pulley coating a shell damage detection, thermography measurements may be used for idlers condition, non-destructive techniques may be applied (measurement of magnetic field of steel cords belt) etc of a conveyor belt transportation system.[34]

Craig, B. et al. (2010) stated two case studies in this paper-

Case study 1 describes the Australian-developed modeling software to enhance the control scheme that increase coal yield and reduce water usages in coal handling preparations plant.

Case study 2 describes the cause of operator graphics techniques and alarm rationalization system on operator effectiveness in coal handling preparations plant. [5]

Jhosi, M. M. et al. (2010) proposed a performance monitoring system for electromagnetic vibrating feeder of coal handling plant by formulating a mathematical relation of flow rate to operating current. [11]

Gupta, S. et al. (2011) proposed some aspects of Reliability and Maintainability in Bulk Material Handling System Design and Factors of Performance Measure, In Design and selection of bulk Material Handling Equipment and Systems. In this paper, authors discuss some areas of Belt and pneumatic conveying design, excavator stacker and reclaimer surface miners design selection and application, testing and examination of the causes of equipment damages, high pressure grinding roll technology, equipment related injuries, reliability and maintainability of equipment aspects of ore degradation during handling and modeling.[7]

Pal, S. K. et al. (2011) proposed repairing techniques for trailing cables of mobile underground mining equipment. In this paper, authors described an overview of cable construction and its components, methods for reliably locating faults in damaged cables with minimum risk to the cable, methods for repairing trailing cables, and testing procedures for evaluating the quality of constructed splice. The authors are also searched the reasons of damaged cables in underground mines due to highly mobile equipment, poor lighting, restricted operating room and machine operator. So that, immediate repair or replacement of damaged cable is necessary to prevent fires or methane gas ignitions in underground coal mines and to minimize production delays. Repairing usually means splicing, which is the mechanical joining of one or more severed conductors, and replacing the insulation, shield, and jacket. Production is delayed by approximately 1-2 hours while the splice is completed underground or the damaged cable is replaced and sent for repair. Since attempts to repair the original cable decreases the mechanical and electrical properties.[31]

Jayaswal, P. et al. (2012) proposed to implement Jishu Hozen and Kobastu Kaizen application for enhancing the overall equipment effectiveness. In this paper, author focuses improvement and autonomous maintenance is two important activities to enhance equipment performance. And also taken a case study from a leaves spring manufacturing company, an attempt is made to identify the areas of improvement in equipment through Kaizen and Jishu Hozen application. Lastly also used why-why application for root cause analysis. It is concluded that OEE of the equipment is increased from 43% to 68% and labour cost decreases up to 43%, resulting an increase in availability, better utilization of resources, reduction in defects and the cost of labour and increased morale and confidence of employees.[10]

Sankhla, V. S. et al. (2012) proposed to investigate how a small Industry could implement the lean philosophy in own concerned. In this paper, author tries to give some recommendation to a small company in what they should think about if they choose to implement Lean Production. [25]

Tigga, A. M. et al. (2012) addressed a set of NC programs which is prepared to drive the CNC machining process of tool path motion trajectory of the cutter center. In this paper, authors have generated the geometry to design a tool trajectory through MATLAB program and introduce to IGES READER for its parametric data extraction. Then after the extracted control point is the raw material for MATLAB program to generate required cutter contact point for tool motion in the complicated spline trajectory. IGES READER software is prepared through DEV C++ platform.[24]

Amardeep, R. et al. (2013) proposed line balancing as an effective tool for improving the overall efficiency of the single model assembly line by reducing the nonvalue-added activities, cycle time, and distribution of workload at each workstation. In this paper, author includes calculation of cycle time of the process, identifying the nonvalue-added activities, calculating total workload on station and distribution of workload on each workstation.[1]

Boban, B. et al. (2013) implemented TPM technique in industries for enhancing the overall equipment effectiveness. As a result availability, reliability, maintainability and safety (RAMS) can be increased. In this paper author plans for implementing TPM which are 5S, Jishu Hozen, Kaizen and abnormality classification leads to more equipment effectiveness in the company.[4]

Hanoun, S. et al. (2013) presented an effective heuristic for planning stockpiles and coal age in the stock yard. A model of stockyard operation within the coal mine is described and the problem is formulated as a Bi-Objective-Optimization problem (BOOP). Both the model and heuristic acts as a decision support system for the stock yard planner. [8]

Kajal, S. et al. (2013) proposed a steady state availability optimization of the Coal handling system by using Matlab Genetic Algorithm tool. In this paper author presents the values of failure and repair rates taken from maintenance history sheet and optimize it from 96.20% to 98.87% i.e. the increase of 2.67% through mathematical formulation and is carried out using probabilistic approach and Markov birth – death process is used to develop the Chapman-Kolmogorov difference differential. In order to achieve the optimum availability level, the corresponding repair and failure rates of the subsystems should be maintained. The failure rates can be maintained through good design, reliable machines, proper preventive maintenance schedule and providing standby components etc. The corresponding repair rates can be achieved by employing more trained workers and utilizing better repair facilities. [13]

Kuttalakkani, M. et al. (2013) proposed a radar-based sensor system on PIC Microcontroller (microchip) for effective handling of the Thermal power plant. In this paper, a real-time temperature monitoring system is developed to collect the range and temperature information of coal. The range information is used to start the conveyor belt to draw the coal from coal yard. Temperature data is used to protect it from combustion. A fire sensor is also used to extinguish the fire by initiating the water spraying system. All the sensors are interfaced with a PLC microcontroller. [14]

Lodhi, G. (2013) proposed an operation and maintenance of crusher house to keep equipment running in good working condition, extend equipment life, improve the quality of operation and reduce operating costs for plant efficiency improvement. In this paper, author presents a suitable approach in inspection methodologies to the identify the critical areas where failures are likely to occur and select suitable techniques for detection of such failures based on design criticality, past experience, and previous failure information. [17]

Mishra, S. et al. (2013) emphasized the use of GPS in DCS for a prevalent and indispensable optimized control and monitoring system in coal handling plant. In this paper location and position information at the dynamic machinery in coal handling plant (CHP) is gathered by the wireless network. This information is used to construct the global view of the monitoring phenomenon or objects. [18]

Pal, A. (2013) proposed to enhance the productivity and to lower the running cost of gear shaft in tippler section. In this paper, author investigates the failure of gear shaft in theoretical basis and also suggesting the remedial measures. So that life of the shaft is increasing near about three years i.e. 25000 hrs which also depends upon mechanical maintenance like lubrication and oiling. [21]

Sharma, S. (2013) proposed for reduction of failure in stacker cum reclaimer for thermal power plant. In this paper author installs safety devices such as impact idlers for reducing the impact wear of the belt due to force produced on the belt at the time of loading, programmed interlocking for protection of damage to the belt,Electro Hydraulic Thruster Brake for smooth stopping of the bucket, Electronic speed switch for overloading, Rotary cam limit switch for protection of boom to over yard conveyor, Travel Limit Switch for stopping travel at either end of pile or reverse when it strikes, Automatic Rail Clamp for drifting of the machine in storm condition. It maintains the stacker cum reclaimer for reducing the breakdown in all operating conditions. [27]

Sardan, M. B. et al. (2013) diagnosed the cause of the damage of the bucket wheel excavator crawler chain link. In order to identify the causes, the author performed stress state calculation as well as experimental investigation such as nature of failures like visual detection, metallographic examination, chemical composition analysis and various test of mechanical properties. Lastly, it concludes that the chain link breakdowns are caused by manufacturing defect. [29]

Shaout, A. et al. (2013) proposed stage-wise fuzzy reasoning model for a performance rating of employees in an organization. In this paper, author presents performance appraisal system for identifying and correcting disparities in employee's performance on two fuzzy approaches. The first approach that is traditional fuzzy approach consists of five linguistic fuzzy input variables. The second approach classifies the critical elements with their relevance and uses fuzzy logic in multistage approach. Lastly, it is shown that from simulation data, the stage wise fuzzy reasoning has a more logical approach for performance analysis and also give important factor to the different critical element as per organizational goal. [26]

Ibrahim, O. (2013) addressed to implement TQM approaches for continued improvement in an organization. And it is possible if all employees, all functions participate (the importance of teamwork and continuous improvement…etc). In this paper, author presents a comparative analysis of some of the researcher's approaches concerning Total quality Management Applications, Models, principles, and aims. [9]

Zaman, M. et al. (2013) implemented Six-sigma methodology for reducing rejection in a welding electrode manufacturing industry. In this paper, author gives an overall idea about DMAIC (define– measure – analyze –improve – control) technique for problem-solving of rejection of welding electrodes and analyzing the statistical tools like normality testing, process capability analysis using process capability tools and studying the process capability ratios and fish-bone diagram. In define phase-identifying the key problem area and defining the quality characteristics like the diameter of the welding electrode for upper and lower specification limit with process mapping by SIPCO diagram (Supply-Input-Process Output-Customer). In measure phase-selecting appropriate product characteristics by probability plot show diameter values do not follow normal distribution pattern and marked to measure the process capability analysis for overall improving the quality program. In analyzes phase- to identify the root causes for rejection of welding electrodes with the help of fishbone diagram and Pareto analysis concludes diameter variation is the root cause among the probable causes of defective coating, eccentricity and moisture content. In improving phase- brainstorming is carried out for a feasible solution to the problem. In control phase- process control charts and Pareto charts are regularly monitored the diameter readings with quantity and quality of silicate has to be maintained to produce proper quality coating material. [33]

Deniz, V. et al. (2014) studied the influence of coal feed size and coal type on crushing performances through Jaw crusher in CHP. The expressed the variation of performance with coal size fraction and coal type. The work concluded for a given coal, as coal fed size decreases strength increases which are due to the distribution of cracks within the coal. [6]

Jyotsna, P. et al. (2014) proposed to minimize the weight of assembly of belt conveyor system and optimized the critical parts like a roller, L-channel support by the geometrical and finite element modeling of existing design. In this paper author tells about Geometrical modeling is done using Catia V5R20 and finite modeling done in ANSYS14.0. Lastly, it is found that Existing design calculation shows the factor of safety is very greater than a requirement and there is a scope for weight reduction of critical parts like roller outer diameter and roller thickness. [12]

M, Kanmani. et al. (2014) proposed a fault detecting and monitoring sensors that give better accuracy, reliable operation in real-time in order to protect the belt conveyor and also reducing the human errors by using delta series PLC and SCADA. In this paper author mainly tells about the identification of belt conveyor faults by sensing the conveyor by means of providing three types of sensors for (i) identifying the tear up of belt conveyor which can be occurred during overload condition and any other causes, (ii) identifying the oil level reduction which can be occurred when there is a decrease in oil level in the tank which is placed in low tension motor, (iii) sensing the temperature level which can occur during overheating of conveyor motor, sudden fire occurrence in the conveyor. [19]

Rana, Y. et al. (2014) proposed an ultrasonic sensor on PLC to drive the motor which helps to maintain the sufficient level of powered coal in the silos & prevents damage. In this paper, an automatic LED indicating the device is used that indicates the level and volume of coal in the silos or bunker. In this work two DC motor are used for two conveyor belt and a stepper motor for the ultrasonic circuit. The output of LED display is connected to PLC for controlling action. [23]

Velmurugan, G. et al. (2014) presents the troubleshooting of belt conveyor system while handling the bulk material. Due to sticking of material, many problems are occurring, for example, damages in belt conveyor system due to chemical reaction and also causes failures due to carry back of the product. The author proposed a permanent maintenance in strategic basis which is saved the cost of future maintenance and also implemented for regular maintenance, proper lubrication is kept maintain alignment of idlers, greasing and painting reduces corrosion in frames and drum for solution in belt conveyor system for avoiding failures and problems, which causes a huge loss to company. The removal of sticking materials is done by two methods. First one is by using a wire brush which is placing under the conveyor belt; it will remove the sticking materials when the conveyor rotates. The second one method is to use a water spray under the belt conveyor. An additional suggestion has also given to using of dual scrap system on the head pulley and plows in front of the tail pulley for effective running of the conveyor belt, thereby profiting the companies. [32]

2.3 Summary

An extensive study of the literature from all available sources and related directly or indirectly with the present piece of work is presented. The literature survey provides a reviews on several diverse streams of literature on different issues of the topic such as LED indicating device for level and volume of coal in bunker, PLC Microcontroller for temperature monitoring, PLC and SCADA for fault detecting and monitoring, wire brush system for removing the sticky material, failure reduction, investigating the cause of damage and implementation of six sigma, QC tools and TPM with their technique. But these methods fail in maintaining the good efficiency as well as to increase the plant productivity of coal handling equipment. In the research, I have solved the problem by (increase the efficiency & plant productivity) of coal handling equipment. The above statements help us to understand the extent and direction of research which are carried out in this present work. Literature of the past dating back to the present time are explored. A comprehensive presentation is attempted through the present work for the benefit of the readers.

Chapter 3

MAJOR EQUIPMENT OF COAL HANDLING PLANT

3.1 Overview

This chapter presents the details and sequential steps of equipment for unloading of coal by wagon tippler to stack yard for storing. It describes the details of equipment and its component for handling the coal.

3.2 Selection of Equipment

There are many equipment and methods for handling the coal in destination plant. This research work consists of six equipment in cyclic order such as tippler, side arm charger, reversible apron feeder, belt conveyor system, stacker, and reclaimer.

3.3 Tippler for Wagon Unloading System

3.3.1 Introduction

The material is received at the process plant by two different types of wagons as indicated above viz. BOXN wagons and BOBRN wagons. Different types of wagon unloading systems are adopted for unloading the material from these wagons. Generally, the material is discharged from the top from the BOXN wagons, while in the case of BOBRN wagons, it is discharged from the bottom. The hopper is provided below the ground for receiving the unloaded material from these wagons. Hence, the BOXN wagons need to be tilted for unloading the material into the hopper while the BOBRN wagons are provided with pneumatically operated gates at the bottom for unloading the material.

3.3.2 Wagon Tippling System

The wagon tippling system consists of wagon tippler, the wagon positioning equipment, underground hopper, and feeder below the hopper for evacuating the material unloaded into the hopper.

3.3.3 Wagon Tippler

Wagon-Tippler is a mechanism used for unloading certain cars such as a wagon, hopper cars etc. it holds the rail car to a section of track and rotates track and car together to dump out the contents such as coal, iron ore etc.

The tippler structure consists of two drum-like cages resting on the eight support roller assemblies in which the coal wagons are rolled over and tipped to offload the coal. The coal falls onto a conveyor system which transports it to the grading plant.

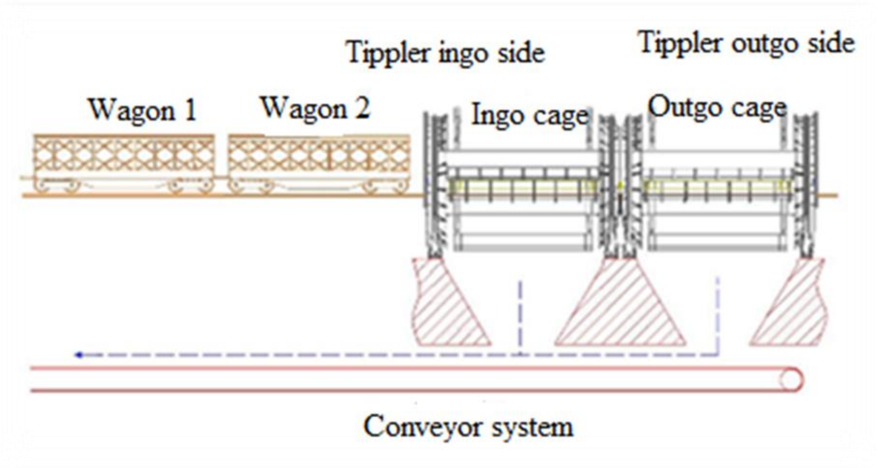

Figure 3.1: Tippler process layout.

The wagon tippler consists of a table for positioning the wagon, wagon holding mechanism, gears and pinions for rotation, drive unit, hydraulic power pack etc. The unloading cycle starts when the wagon is positioned over the wagon tippler table and the wagon along with the table rotates and discharges the material into the underground hopper. The time taken for the unloading operation is about 90 seconds. There are two types of wagon tipplers viz. rotaside which rotates about 135° and another rotary type which rotates by 180°. The rotaside wagon tipplers are provided in most of the plants in India. The drive for the rotation is the hydraulic type for smoother operation.

The main components of wagon tippler are as follows

I. Cradle
II. Tippler platform
III. End rings
IV. Side support beam
V. Top clamp assembly
VI. Drive unit

I. Cradle

The cradle is a frame of the table, comprising two main girders, braced together. Both the rails are fitted on the two main girders. When tippler is in the down position the cradle rest on the two cup & cones and two rollers connecting two stools located on the concrete pedestals or two beams located on the top of the weighing machine(if supplied) and it is isolated from any other form of support in order to ensure correct weighting.

The cradle is pivoted in the slotted bearing, attached to toes by hinge pivot. These pivots are positioned off center to the rail track to ensure the tilting tendency in order to bring the wagon against the side bolster during the initial part of the operating cycle. The cradle has an adequate walkway on it. Sections of check rails are provided inside the rail gauge to restrict the wagon wheels in the tipped positions.

II. Tippler platform

The platform is a bridge-shaped structure. It has a length sufficient to accommodate one 8-wheeler (or two 4-wheeler) bogie type broad gauge open wagon which is to be tipped. The table is constructed of rolled steel joints with standard steel rails (60 kg/meter) mounted on it. The table is pivoted from arms extended from the sectors. The table is covered with chequered plates between the rails.

III. End rings

A pair of end rings with gear sectors mounted on the periphery will be driven by two pinions fixed on the line shaft driven through a suitable drive unit. Each of end rings is trunnion mounted for the purpose of rotation. These end rings are built in the form of semicircle by a suitably designed plate structure.

The center of the end rings is reinforced to carry the trunnion shafts; each of these shafts, in turn, is supported on pivot bearing resting on foundations. On each ring is attached an arm known as “toe” that carries the slotted bearing and support the cradle and bearing during operation. Part of end ring is filled with concrete to provide the counterweight. This counterweight reduces the amount of work required during the tipping on the wagon.

IV. Side support beam

Full face contact between the side support beam and the side stanchions is ensured. The side support extends from a height of 1000 mm up to 2950 mm, from rail level, i.e. contact the side of the wagon over a width of not less than 1950 mm. There is metal to metal contact between the side support beam and the side stanchions of the wagon i.e., no rubber pad or any other alternative are provided on the contact face of the side support beam. The side support beam is the movable type, the movement being done by hydraulic arrangement (No external or movable counterweights should be used with the side support beam). Facility of forward/backward movement should exist, such that it should be move & touch the wagon without applying any pressure on the wagon side wall. Movement of the side support should be controlled and the speed should be crawling just before making contact with the wagon side wall.

Behind this beam assembly are the spill plates designed to facilitate the discharge of the contents of the wagons without spillage.

V. Top clamp assembly

The wagon tippler is equipped with four hydraulically operated steel clamping arms moving through the hydraulic cylinder. All the clamps are designed to more into position as the wagon tippler begins to rotate, and they clamp on the top of the wagon at a pre-determined angle and hold the wagon firmly until it returns to its normal resting position, when the clamps release the wagon. The clamping system is designed so that it can clamp both the maximum and the minimum height of the wagon being tipped. The clamping system is capable of holding a fully loaded wagon at any position during the operation.

VII. Drive unit

The drive unit is either electromechanical or hydraulic. The electromechanical drive consists of an electric motor coupled with a speed reduction gear box and brake mounted on the input shaft of the gearbox. A hydraulic drive consists of a power pack with an electric motor and a hydraulic motor coupled with a helical gear box. The brake is built into the hydraulic motor, and an external hydraulic thrusters brake is mounted on the input shaft of the gearbox.

3.3.4 Wagon Positioning Equipment

There are different types of wagon positioning equipment like hydraulically operated side arm charger, beetle charger and shunting locos. The hydraulically operated side arm chargers are being used in most of the plants in India as this equipment is much faster compared to the others. The tractive force of the side arm charger is suitable for hauling one fully loaded rake.

3.3.5 Unloading Hopper

The hopper provided below the wagon tippler could be either RCC type or structural steel fabricated type. In most of the plants, this will be of RCC construction. The suitable liner is provided for this hopper depending on the abrasiveness of the material handled. Generally, steel grids of 250 mm square are provided above the hopper to avoid higher size of material going through. The higher size material is removed and broken separately and then passed through the grid. The grid is sloping outwards for easy removal of such larger size material.

3.3.6 Feeder below Hopper

The feeder below the hopper could be either vibrating type feeder or apron feeder. The apron feeder is more suitable for heavy duty application for taking the impact of the falling material. The apron feeder is driven by the hydraulic motor for smoother operation.

3.3.7 Rail Tracks

The layout of the rail tracks is such that the track will be straight and horizontal for one rake length on the inhaul side and also on the outhaul side. This is preferable for achieving faster unloading rate and the effort required by the side arm charger would also be minimum. In case it is not possible to have the straight length to accommodate one full rake on either side, then shunting operation is required using the plant loco and hence, it takes the turnaround time more.

3.3.8 Dust Control System

Plain water spray type dust suppression system is provided for suppressing the dust generated during the unloading operation. Spray nozzles are provided at the top of the wagon tippler and also around the hopper for spraying the water and settling the dust. An enclosed shed is provided for the wagon tippler so that the dust is contained within and not spread to the other parts of the plant.

3.3.9 Control Room

A control room is provided adjacent to the wagon tippler at an elevated position for operation and control of the wagon tippling system. The complete view of the unloading system is available from this control room. Generally, the time taken for unloading the rake is about 4 hours with one wagon tippler in operation.

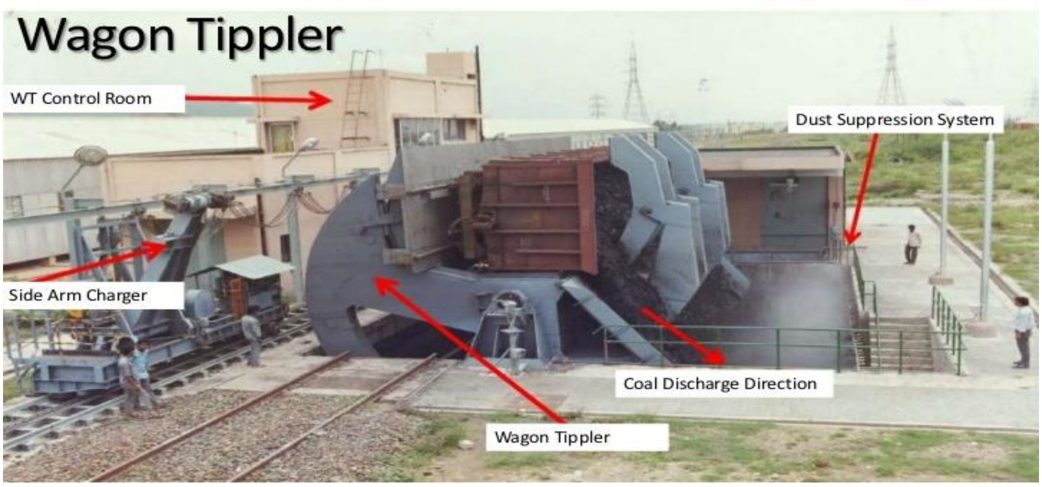

Figure 3.2: A typical operation in Wagon-Tippler section.

3.4 Side Arm Charger

The Side Arm Charger (SAC) is used for wagon positioning at the wagon tippler for unloading of materials. It is used for pushing / pulling a rake of 59 wagons one by one on tippler.

3.4.1 Working principle

A train of 59 loaded wagons is brought in by a locomotive pushing/ pulling and stopped with the leading wagon within the range of the Side Arm Charger using trackside marker boards (under bidder's scope). Bidder is known as contractor, supplier or vendor who responds to an invitation to bid the tender. The work in the range or scope of bidder's is known as bidder scope. The loco is decoupled and despatched and the charger is driven to the leading wagon. Its arm can be lowered and it can be coupled to the first wagon of the train. The train is hauled forward by the charger until the front of the first wagon is about 4 meters away from the tippler. The charger is stopped and the first wagon is uncoupled from the train. Then, the charger is forwarded onto the leading wagon, which forward onto the tippler. This automatically decouples the charger & its arm is raised before it travels back to the train. The tippler is rotated for tippling the wagon. On reaching near the standing train, the charger arm is lowered and coupled to the train ready for repeating the cycle. In the next cycle, the train is drawn up by one wagon length, the front wagon is decoupled & the next cycle is repeated. When the next wagon is located on the tippler table the previously tippled wagon is ejected simultaneously. On the outhaul side, the empty wagon forms a new train ready for collection by a locomotive.

3.4.2 Description of side arms charger

The Side Arm Charger consists of hydraulic power pack, power supply system, supports, electrics, buffer stop, rack & pinion, control cabin, automatic coupler/decoupler etc.

The main component of side arm charger is as follows

I. Structural components
II. Charger frame
III. Drive unit
IV. Lubrication system

I. Structural components

The Side Arm Charger runs on its own track parallel to the main track. It has a stroke of suitable length from a point on the inhaul side of tippler to a point on the outhaul side. It is fitted with an arm pivoted at right angles and operated through a hydraulic system for raising and lowering. The arm has an automatic coupler to couple/decouple the wagons.

II. Charger frame

The charger frame consists of a single fabricated frame on which every other item is directly mounted to form a robust compact unit. The charger runs on four steel wheels mounted on spherical roller bearings. To resist the moment reaction of the pushing force, two pairs of steel side guide rollers is fitted. They are fitted on spherical roller bearings and have a simple lockable adjustment for true running and to take up wear. The side guide rollers run on the sides of the rail heads of the charger running track. The arm is of welded construction.

III. Drive

A side arm charger is hydraulically driven through rack and pinion arrangement. The charger is electrically interlocked with tippler for proper sequential operation with respect to operational & safety requirements. Easy access, adequate maintenance spaces, working platforms, inspection covers are provided for all the equipment located in the Side Arm Charger for safe and quick maintenance. All edges and openings are provided with guards. Chequered plates on the floor are provided to prevent slipping.

IV. Lubrication system

A Centralized system of lubrication is provided for the equipment. However, all parts of the equipment needing manual lubrication are easily accessible. All oil pipes and grease nipples are well covered to prevent damage from materials from falling on them.

Fig 3.3: A snapshot of Side Arm Charger positioning the wagon in Tippler area.

3.5 Reversible Apron Feeder

3.5.1 Introduction

A Reversible Apron Feeder is a mechanical device which transmits the coal to the belt conveyor received from the bunker.

3.5.2 Description of RAF

The main components of Reversible Apron Feeder are as follows

Frame: The frame is manufactured from rolled steel section welded and bolted together to form a rigid structure.

Roller: The roller is lifetime lubricated and is manufactured from alloy steel.

Chain link: The chain Link is forged steel. Pins and rollers are of hardened steel.The chain link is bolted to the pans.

Apron/Pan: Apron/pan is of suitable thickness which is constructed out of fabricated MS with wear resistant liner plate or special alloy steel without any liner plate for the duty requirement. The pan is fitted directly to the chain attachment.

Sprocket: The head and tail end are of sturdy steel construction suitably stiffened. The sprocket is made of cast alloy steel with case hardened teeth or forged steel.

Traction wheel: The traction wheel is made of cast steel with case hardened surface.

Dribble belt system: Complete dribble belt system consisting of the head pulley, tail pulley, drive, motor, stringers, deck plates etc. is provided.

3.6 Belt Conveyor

The belt conveyor is an endless belt moving over two end pulleys at fixed positions and used for transporting material horizontally or at an incline up or down.

3.6.1 Component of belt conveyor

The main components of a belt conveyor are:

I. The belt that forms the moving and supporting surface on which the conveyed material rides. It is the tractive element. The belt should be selected considering the material to be transported.

II. The idlers, which form the supports for the carrying and return stands of the belt.
III. The pulleys that support and move the belt and controls its tension.The drive that imparts power to one or more pulleys to move the belt and its loads.
IV. The structure that supports and maintains the alignments of the idlers and pulleys and support the driving machinery.

Other components include:

V. Loading chute or feeder chute that organizes the flow of material and directs it on the belt conveyor.
VI. Take-up-device which is used to maintain the proper tension of the belt for effective power transmission.
VII. Belt cleaner that keeps the belt free from materials sticking to the belt.
VIII. Tramp removal device, which is optionally used in case the conveyed material bears the chance of having tramp iron mixed with it and subsequent handling of the material, demands its removal.
IX. Discharge chutes to guide the discharged projectile to a subsequent conveyor or another receiving point.
X. Surge hopper and feeder, which is essential for supplying material to the conveyor at the uniform rate when the supply of material is intermittent.
XI. Tripper arrangement to discharge material at a different point or to another device.

3.6.2 Application

I. Conveyor belts are widely used in mineral industry. Underground mine transport, opencast mine transport, and processing plants deploy conveyor belts of different kinds to adopt the specific job requirements. The main advantages of conveyor belt system are:
II. A wider range of material can be handled which cause problems in other transportation means. Belt conveyor can be used for abrasive, wet, dry, sticky or dirty material. The lump size of the transported material is limited by the width of the belt. Belts up to 2500 mm wide are used in mining industry.
III. Higher capacity can be handled than any other form of the conveyor at a considerably lower cost per ton kilometer. Conveyor belts with a capacity

of 11000 t/h and even higher can be deployed to match with higher capacity mining machinery.

IV. Longer distances can be covered more economically than any other transportation system. A single belt conveyor or a series of belt conveyors can do this. Belt conveyors can be adapted for cross-country laying.

V. By the use of many forms of ancillary equipment such as mobile trippers or spreaders, bulk material can be distributed and deposited whenever required.

VI. Many other functions can be performed with the basic conveying like weighing, sorting, picking, sampling, blending, spraying, cooling, drying etc.

VII. Structurally it is one of the lightest forms of the conveying machine. It is comparatively cheaper and supporting structures can be used for many otherwise impossible structures such as crossing rivers, streets, and valleys.

VIII. The belt conveyor can be adopted for special purposes (fire resistant, wear resistant, corrosion resistant, high angle negotiation etc.) and can be integrated with other equipment.

IX. It can be horizontal, incline or decline or a combination of all.

X. Minimum labour is required for the operation and maintenance of belt conveyor system.

XI. In underground mine transport, belt conveyor can be used in thin seams as it eliminates the rock works that might otherwise be required to gain haulage height. Moreover, belt conveyor can provide continuous haulage service from pit bottom to the surface.

3.6.3 Limitations of conveyor belt

The limitations of conveyor belt are:

I. The loading and transfer points need to be properly designed.

II. Numbers of protective devices have to be incorporated to save the belt from getting damaged by operational problems.

III. The belt needs higher initial tension (40-200% of useful pull).

IV. Causing poor productivity.

3.6.4 Idlers

Idlers are mounted on a support frame, which can be shiftable or permanent. The carrying side of the belt is supported on the carrier rollers sets. A set of three rollers is arranged to form a trough for the troughed belt conveyor. The return side of the belt is supported on straight return idlers. The spacing of the idlers is determined based on the belt sag between the idlers. The sag depends on the belt tension, belt width, belt properties and the payload per meter of the belt. The idlers are specified by its length and diameter. These parameters are selected based on the required belt speed for the particular width of the belt.

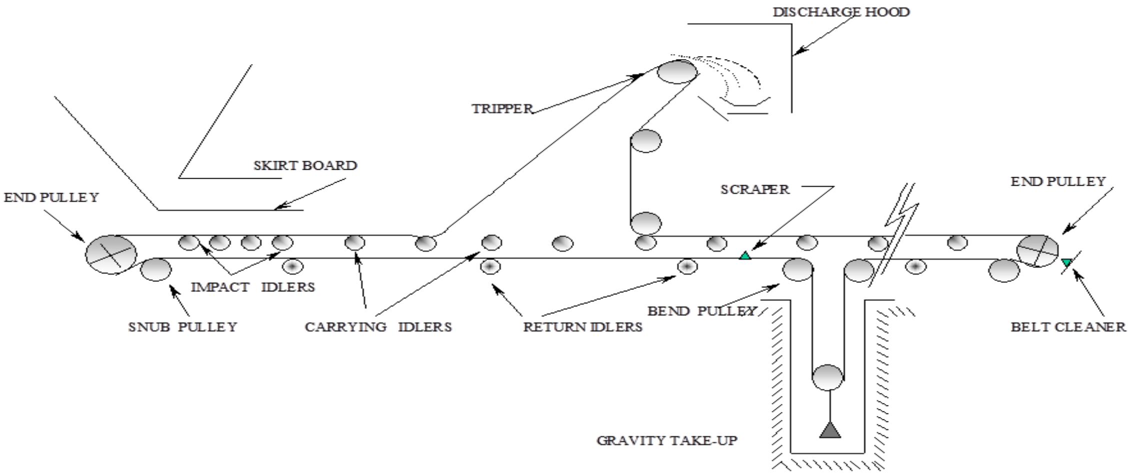

Figure 3.4: Components of the belt conveyor.

3.6.5 Pulley

A conveyor belt system uses different types of pulleys like end pulley, snub pulley, bend pulley etc. The end pulleys are used for driving and sometimes for making tensioning arrangements. Snub pulleys increase the angle of wrap thereby increasing the effective tension in the belt. The pulley diameter depends on the belt width and belt speed.

Pulleys are used for providing the drive to the belt as well as for maintaining the proper tension to the belt.

3.6.6 Drive

Belt drive is provided normally at the discharge ends, however, it may be provided through the head end or through intermediate pulley by coupling the pulley shaft to the reducing gear's output shaft. The coupling is selected based on the load characteristics and applications. Flexible coupling or fluid couplings are often used.

3.6.7 Take-up

The purposes of take-up are:

I. To allow for stretch and shrinkage of the belt.
II. To ensure that the minimum tension in the belt is sufficient to prevent undue sag between idlers.
III. To ensure that the tension in the belt in the rear of the drive pulley is sufficient to permit such pulley to transmit the load.

3.6.8 Conveyor Support

The support of conveyor is normally a structural frame. Depending on the situation the structure can be mounted on the floor or on a skid. The main job of the support is to let the belt run without getting skewed. Depending on situations the support can be made moving type. In such cases idler, a wheel mounted or crawler mounted platform keeps the necessary provision to support the idlers on which the conveyor runs.

3.7 Stacker

3.7.1 Introduction

A stacker is a large machine used in bulk material handling. Its function is to pile bulk material such as coal, limestone, and ores onto a stockpile. Stackers are nominally rated for capacity in tons per hour (mph). They normally travel on a rail between stockpiles in the stockyard. A stacker can usually move in at least two directions: horizontally along the rail and vertically by luffing (raising and lowering) its boom. Luffing of the boom minimizes dust by reducing the distance that material such as coal needs to fall to the top of the stockpile. The boom is luffed upwards as the height of the stockpile increases. Some stackers can rotate the boom. This allows a single stacker to form two stockpiles, one on either side of the conveyor.

3.7.2 Component of Stacker

I. Structural Steel Work
II. Boom Conveyor

III. Boom Luffing Arrangement
IV. Slewing Arrangement
V. Hydraulic system
VI. Chute and skirt board

I. Structural Steel Work

All parts are conveniently arranged for ease of access with special attention being paid to the requirements for maintenance of machinery. To facilitate the maintenance of the various parts, it is full of web construction and adequate walkways, ladders etc are provided for convenient operation.

II. Boom Conveyor

The reversible boom conveyor drive is mounted on a drive frame and is supported on the revolving frame by a torque arm with plain spherical rod ends. The bearing housings supporting the discharge pulley assembly on either side are supported on sliding blocks at boom head. The movement of the bearing blocks for the purpose of adjustment of belt tension and belt changing is achieved through screwed spindles. Belt sway, pull cord and belt clip monitor switches are included for protection of the conveyor.

III. Boom Luffing Arrangement

The raising and lowering of the hinged bascule system and controlling it in operation is achieved by a hydraulic system with two hydraulic cylinders. The cabin is also maintained level automatically by a hydraulic cylinder fed simultaneously from this system. The power pack also includes an independent system for actuation of the chutes etc. and is mounted on at the rear of the revolving platform.

IV. Slewing Arrangement

The revolving superstructure of the machine is supported on a large diameter slewing bearing. An external ring gear, bolted to the revolving frame, is driven by two meshing pinions powered by two independent drive units each comprising a squirrel cage motor, slip clutch, brake, and planetary with bevel helical gear reducer. The slew angles are monitored by limit switches. Additional contacts in the limit switch ensure that the boom can only be slewed over the yard conveyor after it has been raised clear of it.

V. Hydraulic system

A hydraulic system basically consists of a hydraulic tank with capacity of 360 litres. It is mounted with a pump which in use the pressure of the flow of oil and power from a motor. The output line from the pump is constructed with a non-return valve which functions and called Direct control valve. After D/C valve, one line is connected with tank and another end is connected to the output.

VI. Chute and skirt board

A conical chute load with stacker and under this chute receiving the end of the boom is situated. There are the three numbers of skirt board at the receiving end and also controlled the spillage generation.

3.8 Reclaimer

3.8.1 Introduction

A reclaimer is a rail-mounted machine used in bulk material handling applications. A reclaimer's function is to recover bulk material such as ores and coals from a stockpile through the scraper shuttle which is taken up the material by endless mounting scraper chains and the blade fastened to them and is feeding onto a belt conveyor that runs laterally along the piles.

3.8.2 Modes of control

Three modes of controls are provided

Scraper chain: The chain drive switches on through a push button which causes the power contactor for the drive motor to pick up. During operation, the chain is supervised by a proximity type speed monitoring device. In case, after a present time delay, the contact of the speed monitoring device in the control circuit has not changed over, the machine is to be stopped automatically, and the failure is indicated in the enunciator in the operator’s cabin. If with the chain running, a drive failure such as missing blades etc., cause the pulses of the speed monitoring device not to be transmitted, then after a present short delay, the chain is switched off. Travel drive: Through a selector switch for ‘fast-slow’ speed selection and another selector switch for ‘forward-reverse’ the travel gear is started in the desired direction. Variable frequency drive (v/f control) has been provided for the travel drive, to which the PLC provides the fast-slow speed command after the necessary speed mode is selected by the operator. However, travel on high (fast) speed is used in ‘manual mode’ of control with lifted up scraper chain for changing the pile (or zero of operation) and the slow speed is for spotting at a stockpile. End position limit switches at the extreme ends of the yard are switch off the drive when actuated.

Hoist drive: The hoisting gear is operated in either fast or slow speed through a selector switch. The drive can be switched on by a selector switch for raise & lower of the boom. In the manual mode, fast speed is used for raising/ lowering of the boom during pile change over. However, slow speed is used in all the three modes. During reclaiming operation, in auto mode, raising/ lowering of the boom is done only in the slow speed. During changing of the pile, both the chains (Booms) are lifted up.

Cable reels: Cable reels are manually ready for operation interlocked with the travel drive. Though thermal releases, the cable reels and scarper are disconnected in case of an overload and simultaneously give audio-visual annunciation in the operator’s cabin.

3.8.3 Component of Reclaimer

I. Main Structure

The main structure is constructed by I-beam and consists of two numbers of boom gear box with motor and another part of the main structure are the electrical cabin and two numbers of slope chute and one no of delivery chute.

II. Boom assembly

The boom is consists of two numbers of the drive sprocket. These drive sprocket is mounted with drive shaft of gear box and two numbers of chain is mounted with two sprocket which supported guide disc and moves clockwise direction with supporting channel. Generally, each boom consists of 72 numbers of buckets.

III. Boom support and luff superstructure

Boom support with rope steel wire rope which is completing grounded with 3 no’s of the pulley in each end and one end rope is fixed with reclaimer body and another end is fixed with movable hoist dream.

IV. Operator cabin

The machine is operated from a driver's cabin (operator's cabin) which has a clear view over the working range of both the booms on the A and B side during reclaiming. All controls and signal devices are centrally installed in the cabin. Signal panel informs the operator continuously the operating condition of the machine. As inter-communication system between driver's cabin and central control room ensures fast exchanges of information and an economic use of the machine.

3.9 Summary

A brief description of coal handling plant equipment is presented in this chapter viz. Tippler, Side arm charger, Reversible apron feeder, Belt conveyor system, Stacker, Reclaimer. It also emphasizes the component of above equipment and how its role in the industries while handling the material being used in coal handling plant for coal transportation. This chapter presents the chronological order of equipment starting from wagon unloading in tippler equipment to reclaimer for reclaiming the material.

Chapter 4

OEE AND DATA ANALYSIS

4.1 Overview of OEE

Overall Equipment Effectiveness (OEE) shows the effectiveness (in percentage) of actual versus ideal performance of the operation in the coal handling equipment. The OEE metric starts with the idea of Theoretical Operating Time. That is the maximum amount of time that, a facility could be open and available for the production process to produce. Scheduled Shutdown time is calculated by subtracting the category of the time from the Theoretical Operating Time. The scheduled shutdown time, includes all the events that should be excluded from efficiency analysis because there is no intention of running production. The leftover available time is the Loading Time and the OEE calculation begins with it.

Availability –Availability takes into account Downtime Loss, which includes any events that stop planned production for a relevant length of time (several minutes or long enough to be defined as an Event). Examples include equipment failures, material shortages, and change over time. Changeover time is included in OEE analysis since it is a form of downtime. Although it is not currently possible to eliminate changeover time, it can be minimized. The remaining available time is called Operating Time. Availability is a percentage and is calculated by dividing the Operating Time by the Loading Time.

Performance – Performance is a percentage and is calculated by the number of actual products (Actual Output) processed divided by the theoretical maximum products (Theoretical Output) that could be processed in the Operating Time. The performance takes into account Speed Loss, which includes any factors that cause the process to operate at less than the theoretical maximum rate. Examples include machine wear, sub-standard materials, operator inefficiency, etc. The remaining available time is called Net Operating Time.

Quality – Quality is a percentage and is calculated by a number of good products processed (Good Output) that pass manufacturing quality standards divided by the total number of products processed, or the Actual Output. Less than 100% Quality Rate indicates Quality Loss. Quality takes into account Quality Loss, which accounts for produced units that do not meet quality standards, including units that require rework. The remaining time is called Full Productive Time. The goal of all operations is to maximize Full Productive Time.

OEE quantifies areas of loss to provide a gauge for measuring the performance of the current operational environment and where to focus the efforts of the operations team for improvements that contribute directly to operating income. OEE is frequently used as a key metric in Lean Manufacturing programs. It provides a consistent way to measure the effectiveness of Lean and other initiatives by providing an overall framework for measuring operational performance.

The following main areas are covered:

OEE: Sources of Business Loss – The primary drivers of business loss within the three OEE components.

Six Big Losses – Production processes have six common types of waste, better known as the Six Big Losses. The Six Big Losses distinguish the most common causes of business loss in a manufacturing operation.

Calculating OEE – The calculation of OEE is defined.

4.2 OEE: Sources of Business Loss

The three primary components of loss within OEE are Availability, Performance, and Quality which were already defined. The primary drivers of business loss within these three OEE components are:

Downtime Loss – Downtime loss is defined as the time during which automation equipment is not operated, but necessary to be produced. It refers to two sources of loss:

Equipment Breakdowns/Failure – A sudden and unexpected equipment breakdown or failure results in loss of production time. The cause of the malfunction may be technical as well as organizational (i.e. operational error, poor maintenance, etc.). OEE measures the way the breakdown manifests itself.

Equipment Idle Time – Setup and adjustment time where the equipment is idle. The equipment can be idle for many reasons (i.e. changeover, maintenance or work breaks). In the case of a changeover, the equipment usually has to be shut down for some time in order to change tools, dies, or other parts. SMED (Single Minute Exchange of Die) defines the change over time as the time between the last good product of the previous series and the first good product of the new series. For the OEE, the changeover time is the time when the machine does not generate any products.

Speed Loss – Speed loss implies that the equipment is operating, but not at its maximum theoretical speed. There are two types of speed losses:

Reduced Equipment Speed – Reduced speed is the difference between the actual set speed and the theoretical or design speed. There is often a considerable difference between what an operator believes is the equipment's maximum speed versus the theoretical maximum speed. In many cases, the production speed has been optimized in order to prevent other losses such as quality rejects and breakdowns. Losses due to reduced speed are, therefore, often ignored or underestimated.

Minor Equipment Stops – When equipment has short interruptions and does not deliver constant speed then a smooth flow of production does not occur. These minor stops manifest subsequent losses of speed and are generally caused by small problems, such as product units blocking sensors or getting stuck in conveyor belts. These frequent slowdowns can drastically diminish the effectiveness of equipment.

Quality Loss – Loss of quality occurs when equipment performance contributes to products that do not satisfy the company's defined quality criteria. Two types of quality losses are distinguished:

Scrap – Scrap is those product units that do not meet the quality specifications even if they can be sold as "sub-specification". The objective of every company has "zero defects". A specific type of quality loss is the start-up and end up loss.

Rework – Reworked product units do not meet the quality specifications the first time through the process, but can be reprocessed into good products. Reworking products may not seem to be a loss because the product unit can still be sold at the normal price. However, the product unit was not right the first time and is, therefore, a registered as a quality loss just like scrap.

4.3 Defining Six big Losses

One of the major goals of OEE programs is to reduce and/or eliminate the Six Big Losses – the most common causes of efficiency loss in operation. The following table lists the Six Big Losses and shows how they relate to the OEE Loss categories.

Table 4.1: Six big losses with examples.

Six Big Loss Category	OEE Loss Category	Event Examples
Breakdowns	Down Time Loss	• Tooling Failures • Unplanned Maintenance • General Breakdowns • Equipment Failure
Setup and Adjustments	Down Time Loss	• Setup/Changeover • Material Shortages • Operator Shortages • Major Adjustments • Warm-Up Time
Small Stops	Speed Loss	• Obstructed Product Flow • Component Jams • Mis-feeds • Sensor Blocked • Delivery Blocked • Cleaning/Checking
Reduced Speed	Speed Loss	• Rough Running • Under Nameplate Capacity • Under Design Capacity • Equipment Wear • Operator Inefficiency
Startup Rejects	Quality Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • Incorrect Assembly
Production Rejects	Quality Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • Incorrect Assembly

4.4 Calculating OEE

OEE calculation is based on the three OEE Factors, Availability, Performance, and Quality. Here's how each of these factors is calculated.

Table 4.2: OEE calculation.

<table>
<tr><td colspan="5">Total Time</td></tr>
<tr><td colspan="4">Net Available Time</td><td>Scheduled Downtime</td></tr>
<tr><td colspan="3">Operating Time</td><td>Downtime Losses →</td><td>$A = \frac{Operating\ Time}{Net\ available\ Time}$</td></tr>
<tr><td colspan="2">Net Operating Time</td><td>Speed Losses →</td><td>$P = \frac{Net\ Operating\ Time}{Operating\ Time}$</td><td>→ $P = \frac{Actual\ Output}{Target\ Output}$</td></tr>
<tr><td>Fully Productive Time</td><td>Defect Losses →</td><td>$Q = \frac{Fully\ Productive\ Time}{Net\ Operating\ Time}$</td><td>→ $Q = \frac{Good\ Output}{Actual\ Output}$</td><td></td></tr>
</table>

Availability takes into account "lost time" which includes any events that stop planned production for an appreciable length of time. This is usually because of equipment failures, waiting times, and etc. Then, availability is determined as follows:

$$\text{Availability} = \frac{\text{Net Available Time - Downtime Losses}}{\text{Net Available Time}} \times 100$$

The performance takes into account "speed loss", which includes any factors that cause the equipment to operate at less than the maximum possible speed when running. Reasons for that can be substandard materials, operator inefficiency, and job conditions. Then performance is determined as follows:

$$\text{Performance} = \frac{\text{Operating Time- Speed Losses}}{\text{Operating Time}} \times 100$$

Quality takes into account "product loss or filling factor loss", which is determined as follows:

$$\text{Quality} = \frac{\text{Net Operating Time - Defect Losses}}{\text{Net Operating Time}} \times 100$$

OEE takes into account all three **OEE Factors**, and is calculated as:

$$\textbf{\textit{OEE}} = Availability \times Performance \times Quality$$

4.4.1 OEE calculation for Tippler

Wagon-Tippler is a mechanism used for unloading certain cars such as a wagon, hopper cars etc. It holds the rail car to a section of track and rotates track and car together to dump out the contents such as coal, iron ore etc. Their performance and production control the total output of the operation. Therefore, any production loss in tippler section causes an increase in total production cost as well as demurrage charges. Therefore, the possible time losses causes are defined as follows:

Table 4.3: Time loss classification of Tippler.

No	Loss Classification	Description
1.	Nonscheduled time	The time duration for which equipment is not scheduled to operate.
2.	Scheduled maintenance time	Time spent for periodic maintenance of tippler.
3.	Unscheduled maintenance time	Time spent for the breakdown.
4.	Setup and adjustment time	Time spent for setup and adjustment.
5.	Idle time without operator	Equipment is ready but no operator (such as lunch break).
6.	Wagon waiting time	The time duration for which tippler waits to get position to be loaded.
7.	Tippling delay	The time duration for which tippler is stuck up.
8.	Time losses due to job conditions:	Time loss due to management, supervision, climate and job conditions.
9.	Speed loss	Time loss due to the equipment that is operating under the standard speed.
10.	Quality loss	That is equivalent to unqualified products and depends on the fill factor of a tippler.

Table 4.4: Timeline of items for a Tippler Operation & Estimation.

Item	**Description**	**Calculation**
Total Time	**24 hours/day * 365 days/year**	**8760 hrs.**
Non-Scheduled Time i.e. No Production, Breaks, Holidays, Shift Changes….	15 Days Off	360 hrs.
Scheduled Maintenance	3 Hours/ Day * 350 Days	1050 hrs.
Scheduled Time based Approach	Total Time – Scheduled Shut Down	7350 hrs.
Downtime Losses		
A. Breakdowns (Un-Scheduled Maintenance)	Failure of equipment	635 hrs.
B. Idle Time		
Set-up & Adjustment	0.4 Hours/Shift	420 hrs.
Standby Time	0.7 Hours/Shift	735 hrs.
Wagon Waiting Time	0.2 Hours/Shift	210 hrs.
Sub Total Availability Losses (A+B) hrs.	2000 Hour	7350 – 2000 = 5350 5350 ÷ 7350 * 100 =72%
Speed Losses		
C. Tippling Delay	0.3 Hours/Shift	315 hrs.
D. Speed Loss	0.2 Hours/Shift	210 hrs.
Job Condition	Equipment did not work due to rain, snow, fog and others	188 hrs.
Sub Total Performance Losses	713 Hours	5350 – 713 = 4637 4637 ÷ 5350 * 100 = 87%
Defect Losses		
Sub Total Quality Losses	Filling Factor	89%
Overall Equipment Effectiveness	OEE	0.72*0.87*0.89 =56 %
Tippler Capacity	700 Ton	
Ideal Production	220 Ton/hrs.	
Total Production	Total Time ÷ Ideal Production * Tippler Capacity * OEE	93652363 Ton

4.4.2 OEE calculation for Side Arm Charger

The Side Arm Charger (SAC) is used for wagon positioning at the wagon tippler for unloading of materials. It is used for pushing / pulling a rake of 59 wagons one by one on tippler. Their performance and production control the total output of the operation. Therefore, any production loss inside arm charger causes an increase in total production cost as well as demurrage charges. As it is said before that the time losses classification for side arm charger is also different. Therefore, the possible time losses causes are defined as follows:

Table 4.5: Time loss classification of Side arm charger.

No	**Loss Classification**	**Description**
1.	Nonscheduled time	The time duration for which equipment is not scheduled to operate.
2.	Scheduled maintenance time	Time spent for periodic maintenance of SAC.
3.	Unscheduled maintenance time	Time spent for the breakdown.
4.	Setup and adjustment time	Time spent for setup and adjustment.
5.	Idle time without operator	Equipment is ready but no operator (such as lunch break).
6.	Wagon waiting time	The time duration for which SAC waits to get position to be coupled.
7.	Minor stoppage	Time loss due to cleaning/checking of SAC.
8.	Time losses due to job conditions:	Time loss due to management, supervision, climate and job conditions.
9.	Speed loss	Time loss due to the equipment that is operating under the standard speed.
10.	Quality loss	That is equivalent to unqualified products and depends on the fill factor of side arm charger.

Table 4.6: Time line of items for a Side Arm Charger Operation & Estimation.

Item	Description	Calculation
Total Time	**24 hours/day * 365 days/year**	**8760 hrs.**
Non Scheduled Time i.e No Production, Breaks, Holidays, Shift Changes….	15 Days Off	360 hrs.
Scheduled Maintenance	3 Hours/ Day * 350 Days	1050 hrs.
Scheduled Time based Approach	Total Time – Scheduled Shut Down	7350 hrs.
Downtime Losses		
A. Breakdowns (Un-Scheduled Maintenance)	Failure of equipment	490 hrs.
B. Idle Time		
Set-up & Adjustment	0.2 Hours/Shift	210 hrs.
Stand by Time	0.6 Hours/Shift	630 hrs.
Wagon Waiting Time	0.2 Hours/Shift	210 hrs.
Sub Total Availability Losses (A+B) hrs.	1540 Hour	7350 – 1540 = 5810 5810 ÷ 7350 * 100 = 79%
Speed Losses		
C. Reduced SAC Speed	0.1 Hours/Shift	105 hrs.
D. Minor Stoppage	0.2 Hours/Shift	210 hrs.
Job Condition	Equipment did not work due to rain, snow, fog and others	188 hrs.
Sub Total Performance Losses	503 Hours	5810 – 503 = 5307 5307 ÷ 5810 * 100 = 91%
Defect Losses		
Sub Total Quality Losses	Filling Factor	89%
Overall Equipment Effectiveness	OEE	0.79*0.91*0.89 =64 %
Side Arm Charger Capacity	700 Ton	
Ideal Production	27.5nos Wagon/hrs.	
Total Production	Total Time ÷ Ideal Production * SAC Capacity * OEE	107031272.73 Ton

4.4.3 OEE calculation for Reversible Apron Feeder

A Reversible Apron Feeder is a mechanical device which transmits the coal to the belt conveyor received from the bunker. Their performance and production control the total output of the operation. Therefore, any production loss in reversible apron feeder causes an increase in total production cost as well as demurrage charges. As it is said before that the time losses classification for reversible apron feeder is also different. Therefore, the possible time losses causes are defined as follows:

Table 4.7: Time loss classification of Reversible apron feeder.

No	**Loss Classification**	**Description**
1.	Nonscheduled time	The time duration for which equipment is not scheduled to operate.
2.	Scheduled maintenance time	Time spent for periodic maintenance of RAF.
3.	Unscheduled maintenance time	Time spent for the breakdown.
4.	Setup and adjustment time	Time spent for setup and adjustment.
5.	Idle time without operator	Equipment is ready but no operator (such as lunch break).
6.	Material waiting time	The time duration for which RAF waits to receive the material.
7.	Minor stoppage	Time loss due to cleaning/checking of RAF.
8.	Time losses due to job conditions:	Time loss due to management, supervision, climate and job conditions.
9.	Speed loss	Time loss due to the equipment that is operating under the standard speed.
10.	Quality loss	That is equivalent to unqualified products and depends on the fill factor of reversible apron feeder.

Table 4.8: Timeline of items for a Reversible Apron Feeder Operation & Estimation.

Item	Description	Calculation
Total Time	**24 hours/day * 365 days/year**	**8760 hrs.**
Non-Scheduled Time i.e No Production, Breaks, Holidays, Shift Changes….	15 Days Off	360 hrs.
Scheduled Maintenance	3 Hours/ Day * 350 Days	1050 hrs.
Scheduled Time based Approach	Total Time – Scheduled Shut Down	7350 hrs.
Downtime Losses		
A. Breakdowns (Un-Scheduled Maintenance)	Failure of equipment	218 hrs.
B. Idle Time		
Set-up & Adjustment	0.2 Hours/Shift	210 hrs.
Standby Time	0.7 Hours/Shift	735 hrs.
Material Waiting Time	0.3 Hours/Shift	315 hrs.
Sub Total Availability Losses (A+B) hrs	1478 Hour	7350 – 1478 = 5872 5872 ÷ 7350 * 100 = 80%
Speed Losses		
C. Reduced RAF Speed	0.1 Hours/Shift	105 hrs.
D. Minor Stoppage	0.2 Hours/Shift	210 hrs.
Job Condition	Equipment did not work due to rain, snow, fog and others	188 hrs.
Sub Total Performance Losses	503 Hours	5872 - 503= 5369 5369 ÷ 5872 * 100 = 91%
Defect Losses		
Sub Total Quality Losses	Filling Factor	86%
Overall Equipment Effectiveness	OEE	0.79*0.91*0.86 =61 %
Reversible Apron Feeder Capacity	750Ton	
Ideal Production	550Ton/hrs.	
Total Production	Total Time ÷ Ideal Production * RAF Capacity * OEE	43720363.637 Ton

4.4.4 OEE calculation for Belt conveyor

Belt conveyors are a mechanical device which transmit the material from one location to another location by the help of pulley, idler, structure, driving unit etc. Their performance and production control the total output of the operation. Therefore, any production loss in belt conveyor causes an increase in total production cost as well as demurrage charges. As it is said before that the time losses classification for belt conveyor is also different. Therefore, the possible time losses causes are defined as follows:

Table 4.9: Time loss classification of Belt conveyor system.

No	**Loss Classification**	**Description**
1.	Nonscheduled time	The time duration for which equipment is not scheduled to operate.
2.	Scheduled maintenance time	Time spent for periodic maintenance of belt conveyor.
3.	Unscheduled maintenance time	Time spent for the breakdown.
4.	Setup and adjustment time	Time spent for setup and adjustment.
5.	Idle time without operator	Equipment is ready but no operator (such as lunch break).
6.	Material waiting time	The time duration for which belt conveyor waits to receive the material.
7.	Minor stoppage	Time loss due to cleaning/blocking of sensors in belt conveyor.
8.	Time losses due to job conditions:	Time loss due to management, supervision, climate and job conditions.
9.	Speed loss	Time loss due to the equipment that is operating under the standard speed.
10.	Quality loss	Due to fragmentation size and operator ability, the width of the belt conveyor cannot be loaded to its full capacity.

Table 4.10: Timeline of items for a Belt Conveyor Operation & Estimation.

Item	**Description**	**Calculation**
Total Time	**24 hours/day * 365 days/year**	**8760 hrs.**
Non-Scheduled Time i.e. No Production, Breaks, Holidays, Shift Changes….	15 Days Off	360 hrs.
Scheduled Maintenance	3 Hours/ Day * 355 Days	1050 hrs.
Scheduled Time based Approach	Total Time – Scheduled Shut Down	7350 hrs.
Downtime Losses		
A. Breakdowns (Un-Scheduled Maintenance)	Failure of equipment	835 hrs.
B. Idle Time		
Set-up & Adjustment	0.4 Hours/Shift	420 hrs.
Standby Time	0.6 Hours/Shift	630 hrs.
RAF Waiting Time	0.3 Hours/Shift	315 hrs.
Sub Total Availability Losses (A+B) hrs.	2200 Hour	7350 – 2200 = 5150 5150 ÷ 7350 * 100 = 70%
Speed Losses		
C. Reduced Belt Speed	0.2 Hours/Shift	210 hrs.
D. Conveyor belt Minor Stoppage Speed Loss	0.3 Hours/Shift	315 hrs.
Job Condition	Equipment did not work due to rain, snow, fog and others	188 hrs.
Sub Total Performance Losses	713 Hours	5150 – 713 = 4437 4437÷ 5150 * 100 = 86%
Defect Losses		
Sub Total Quality Losses	Filling Factor	84%
Overall Equipment Effectiveness	OEE	0.70*0.86*0.84 = 51%
Conveyor belt Capacity	700Ton	
Ideal Production	500Ton/hrs.	
Total Production	Total Time ÷ Ideal Production * Belt conveyor Capacity * OEE	37527840Ton

4.4.5 OEE calculation for Stacker

Stacker receives the material from belt conveyor and stacking into the stock yard with the help of boom conveyor. Their performance and production control the total output of the operation. Therefore, any production loss in stacker causes an increase in total production cost. As it is said before that the time losses classification for stacker is also different. Therefore, the possible time losses causes are defined as follows:

Table 4.11: Time loss classification of Stacker.

No	**Loss Classification**	**Description**
1.	Nonscheduled time	The time duration for which equipment is not scheduled to operate.
2.	Scheduled maintenance time	Time spent for periodic maintenance of stacker.
3.	Unscheduled maintenance time	Time spent for the breakdown.
4.	Setup and adjustment time	Time spent for setup and adjustment.
5.	Idle time without operator	Equipment is ready but no operator (such as lunch break).
6.	Material waiting time	The time duration for which stacker waits to receive the material.
7.	Minor stoppage	Time loss due to cleaning/blocking of sensors in the stacker.
8.	Time losses due to job conditions:	Time loss due to management, supervision, climate and job conditions.
9.	Speed loss	Time loss due to the equipment that is operating under the standard speed.
10.	Quality loss	Due to fragmentation size and operator ability, the width of the belt stacker cannot be loaded to its full capacity.

Table 4.12: Timeline of items for a Stacker Operation & Estimation.

Item	**Description**	**Calculation**
Total Time	**24 hours/day * 365 days/year**	**8760 hrs.**
Non-Scheduled Time i.e No Production, Breaks, Holidays, Shift Changes….	15 Days Off	360 hrs.
Scheduled Maintenance	3 Hours/ Day * 355 Days	1050 hrs.
Scheduled Time based Approach	Total Time – Scheduled Shut Down	7350 hrs.
Downtime Losses		
A. Breakdown (Un-Scheduled Maintenance)	Failure of equipment	468 hrs.
B. Idle Time		
Set-up & Adjustment	0.3 Hours/Shift	315 hrs.
Standby Time	0.5 Hours/Shift	525 hrs.
Material Waiting Time	0.4 Hours/Shift	420 hrs.
Sub Total Availability Losses (A+B) hrs.	1748 Hour	7350 – 1748 = 5602 5602 ÷ 7350 * 100 = 76%
Speed Losses		
C. Reduced Stacking Speed	0.2 Hours/Shift	210 hrs.
D. Stacker Minor Stoppage (Speed Loss)	0.3 Hours/Shift	315 hrs.
Job Condition	Equipment did not work due to rain, snow, fog and others	188 hrs.
Sub Total Performance Losses	713 Hours	5602 - 713 = 4889 5889 ÷ 5602 * 100 = 87%
Defect Losses		
Sub Total Quality Losses	Filling Factor	79%
Overall Equipment Effectiveness	OEE	0.76*0.87*0.79 = 52%
Stacker Capacity	300 Ton	
Ideal Production	220 Ton/hrs.	
Total Production	Total Time ÷ Ideal Production * Stacker Capacity * OEE	37269804 Ton

4.4.6 OEE calculation for Reclaimer

Reclaimer reclaims the material through a series of chain mounted on it and is dispatched to belt conveyor for next operation. Their performance and production control the total output of the operation. Therefore, any production loss in stacker causes an increase in total production cost. As it is said before that the time losses classification for reclaimer is also different. Therefore, the possible time losses causes are defined as follows:

Table 4.13: Time loss classification of Reclaimer.

No	Loss Classification	Description
1.	Nonscheduled time	The time duration for which equipment is not scheduled to operate.
2.	Scheduled maintenance time	Time spent for periodic maintenance of reclaimer.
3.	Unscheduled maintenance time	Time spent for the breakdown.
4.	Setup and adjustment time	Time spent for setup and adjustment.
5.	Idle time without operator	Equipment is ready but no operator (such as lunch break).
6.	Material waiting time	The time duration for which reclaimer waits to receive the material.
7.	Minor stoppage	Time loss due to cleaning/blocking of sensors in reclaimer.
8.	Time losses due to job conditions:	Time loss due to management, supervision, climate and job conditions.
9.	Speed loss	Time loss due to the equipment that is operating under the standard speed.
10.	Quality loss	Due to fragmentation size and operator ability, the width of the belt reclaimer cannot be loaded to its full capacity.

Table 4.14: Timeline of items for a Reclaimer Operation & Estimation.

Item	Description	Calculation
Total Time	**24 hours/day * 365 days/year**	**8760 hrs.**
Non-Scheduled Time i.e. No Production, Breaks, Holidays, Shift Changes…. (Scheduled Shut Downtime)	15 Days Off	360 hrs.
Scheduled Maintenance	3 Hours/ Day * 355 Days	1050 hrs.
Scheduled Time based Approach	Total Time – Scheduled Shut Down	7350 hrs.
Downtime Losses		
A. Breakdown (Un-Scheduled Maintenance)	Failure of equipment	382 hrs.
B. Idle Time		
Set-up & Adjustment	0.1 Hours/Shift	105 hrs.
Standby Time	0.5 Hours/Shift	525 hrs.
Material Waiting Time	0.4 Hours/Shift	420 hrs.
Sub Total Availability Losses (A+B) hrs.	1432 Hour	7350 - 1432 = 5918 5918 ÷ 7350 * 100 = 80%
Speed Losses		
C. Reduced Reclaiming Speed	0.1 Hours/Shift	105 hrs.
D. Reclaimer Minor Stoppage (Speed Loss)	0.2 Hours/Shift	210 hrs.
Job Condition	Equipment did not work due to rain, snow, fog and others	188 hrs.
Sub Total Performance Losses	503 Hours	5918 - 503 = 5415 5415 ÷ 5918 * 100 = 91%
Defect Losses		
Sub Total Quality Losses	Filling Factor	78%
Overall Equipment Effectiveness	OEE	0.80*0.91*0.78 = 56%
Reclaimer Capacity	350 Ton	
Ideal Production	300 Ton/hrs.	
Total Production	Total Time ÷ Ideal Production * Reclaimer Capacity * OEE	34339200 Ton

4.5 Performance report of coal handling machineries

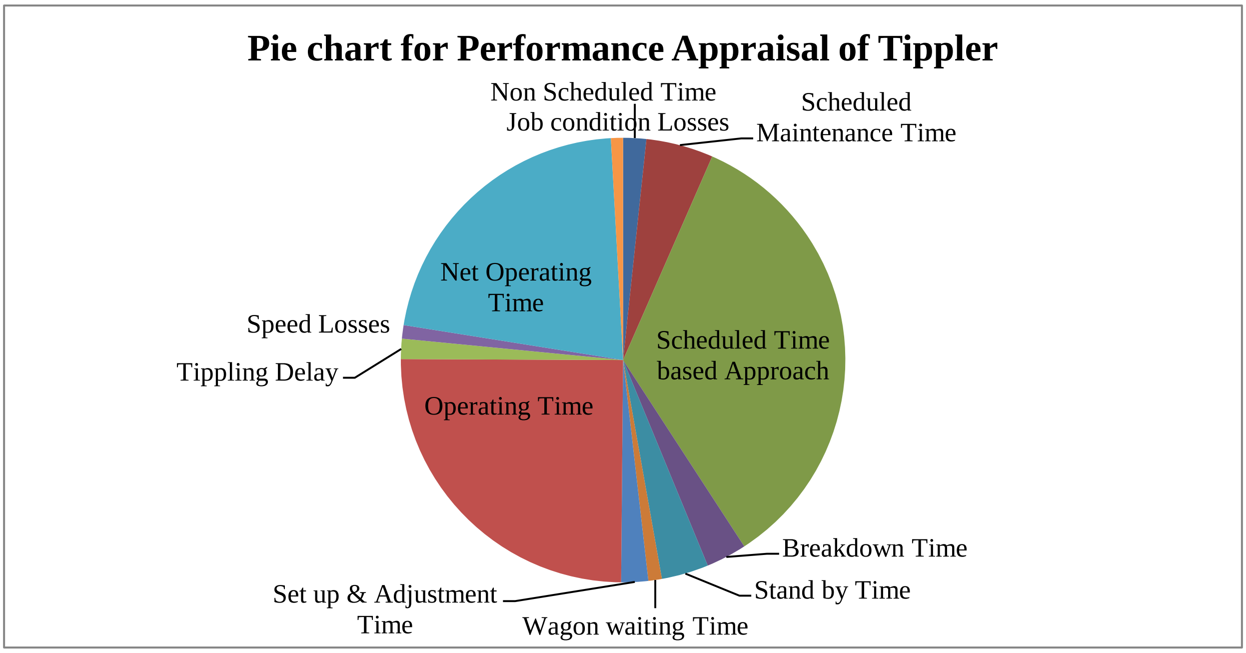

Fig 4.1: Performance appraisal of Tippler.

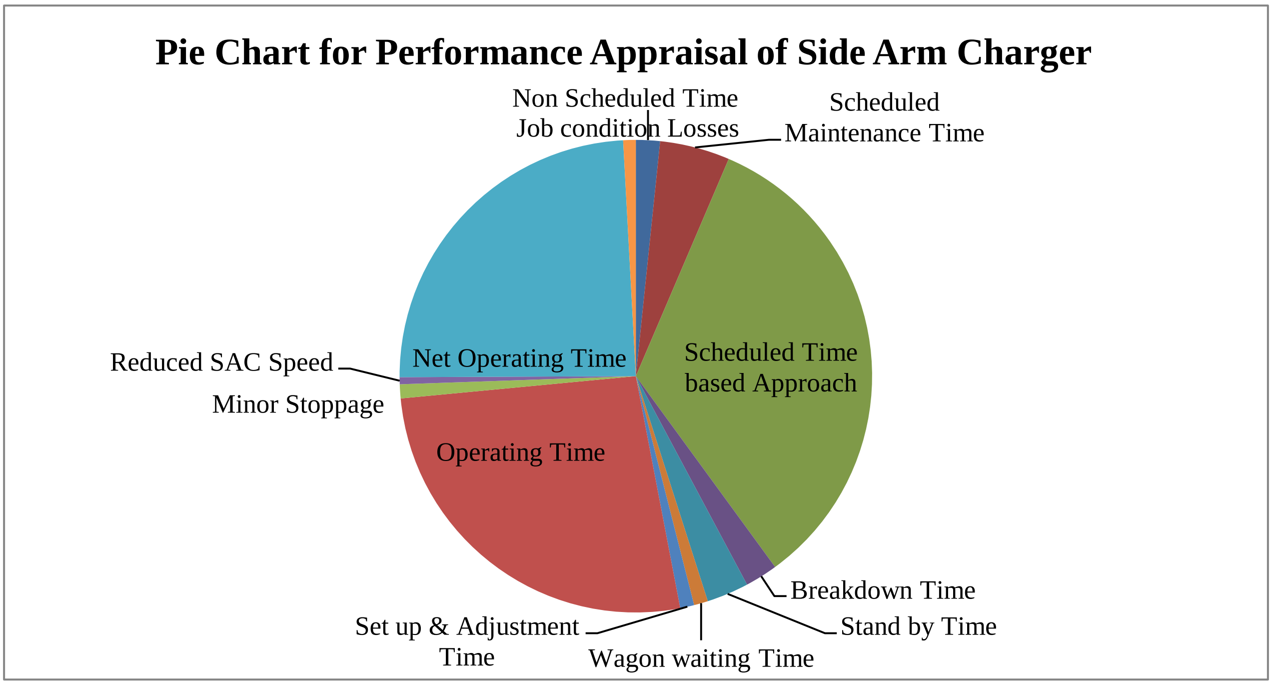

Fig 4.2: Performance appraisal of Side arm charger.

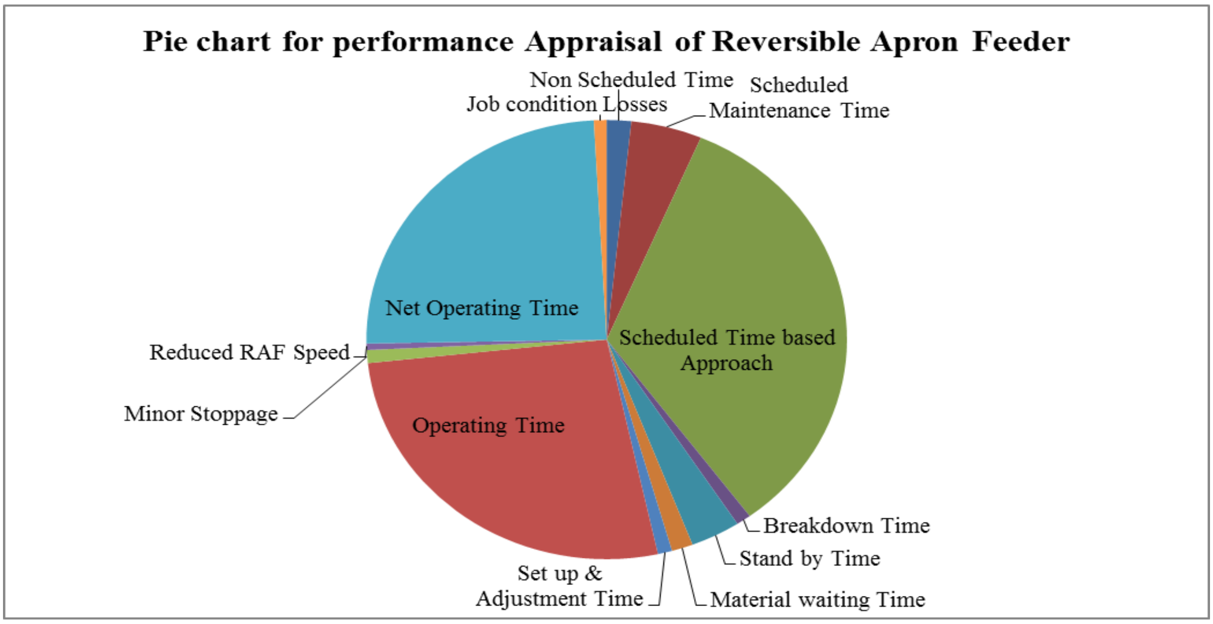

Fig 4.3: Performance appraisal of Reversible apron feeder

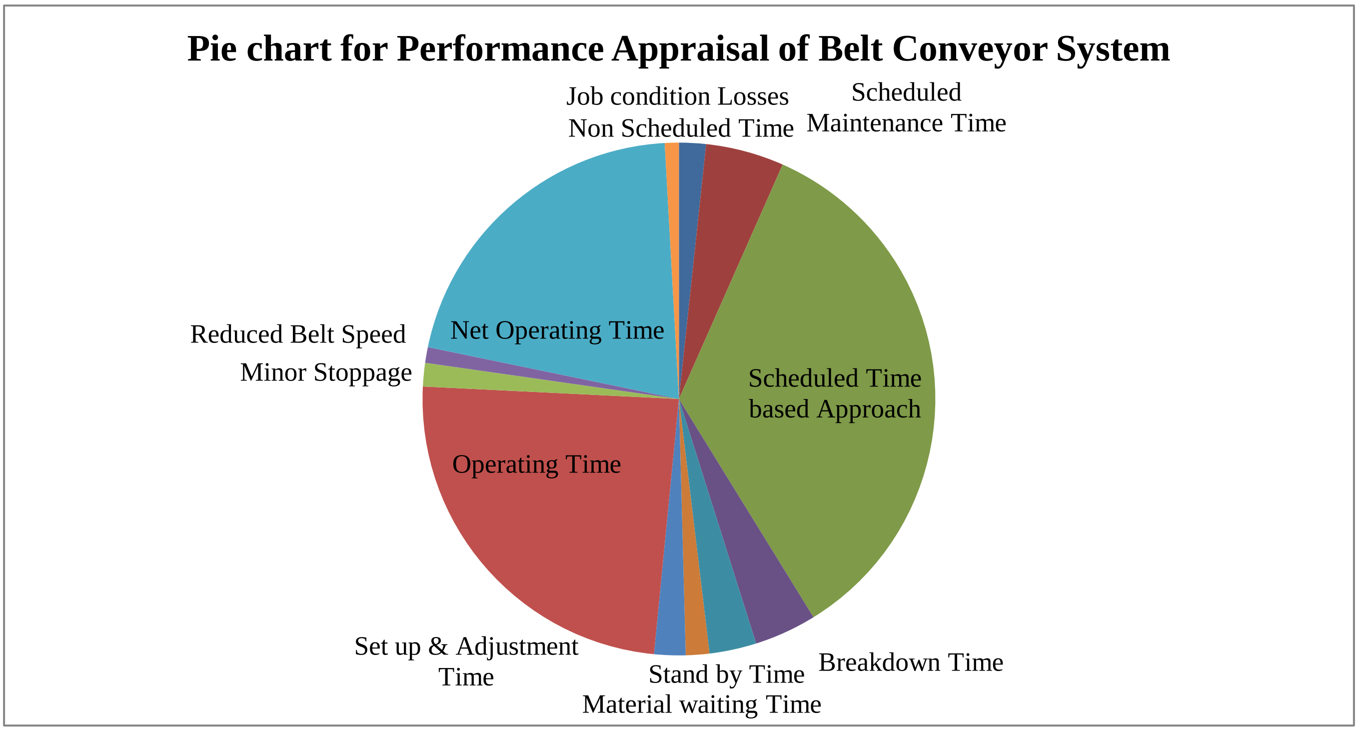

Fig 4.4: Performance appraisal of Belt conveyor system.

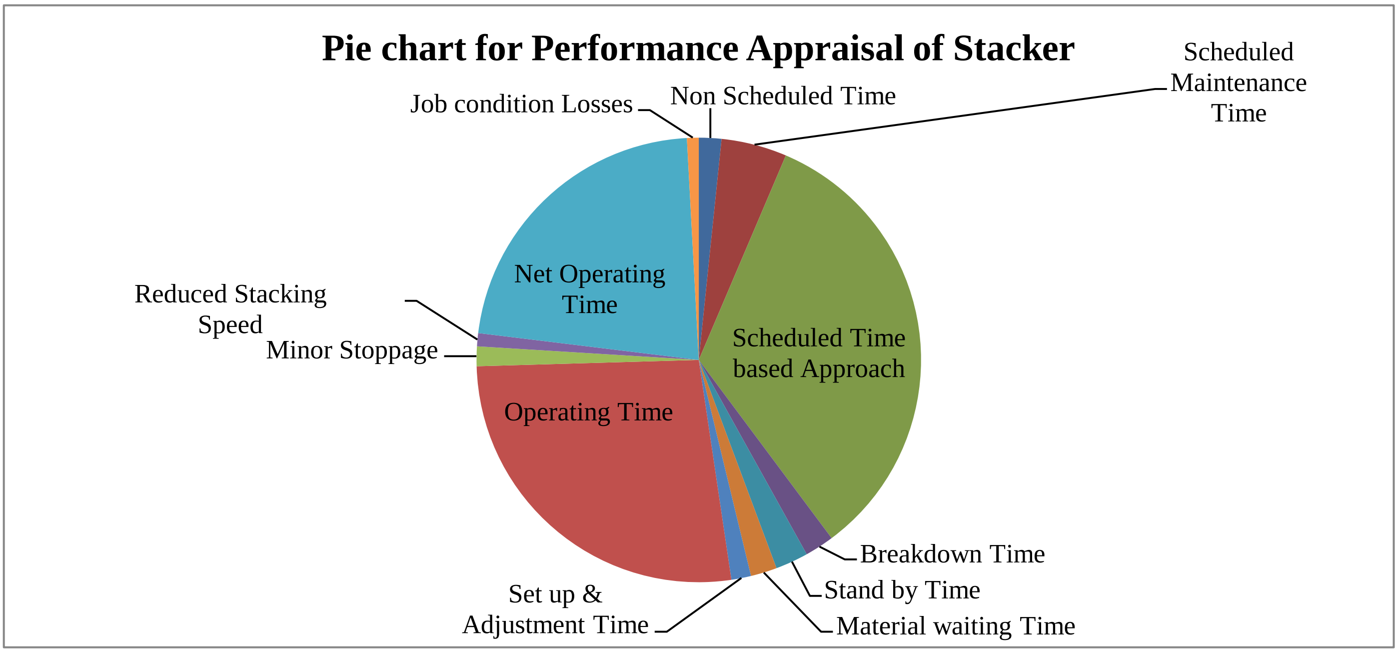

Fig 4.5: Performance appraisal of Stacker.

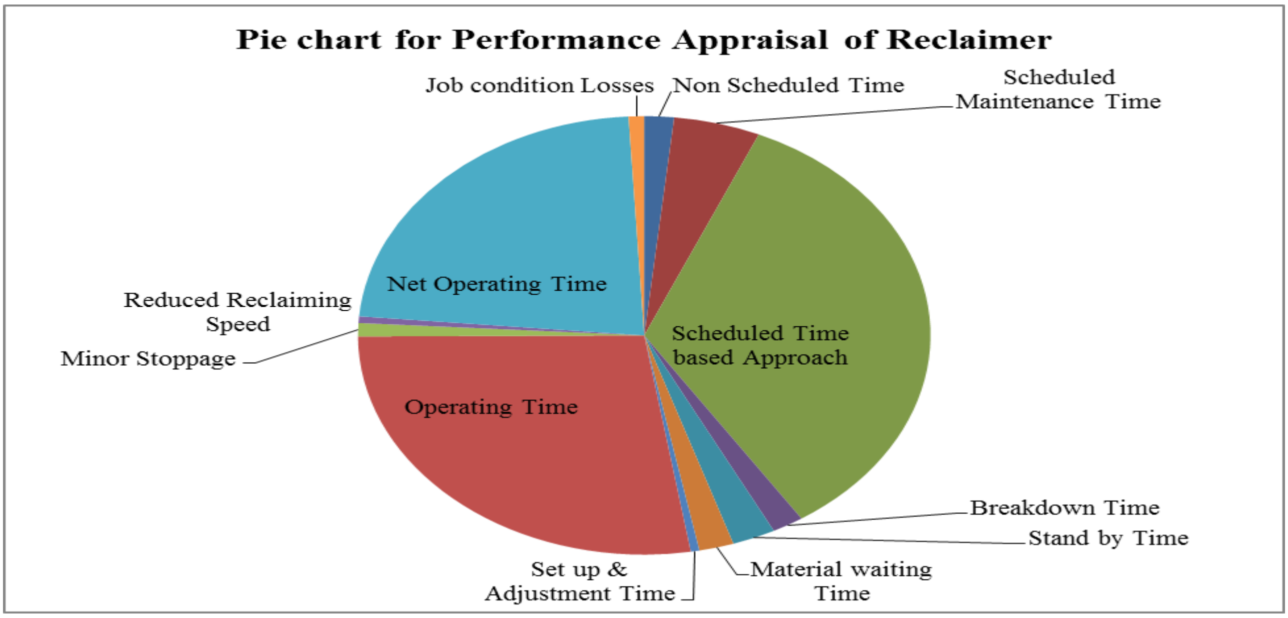

Fig 4.6: Performance appraisal of Reclaimer.

4.6 Comparison of World Class OEE to Obtained OEE for Tippler equipment

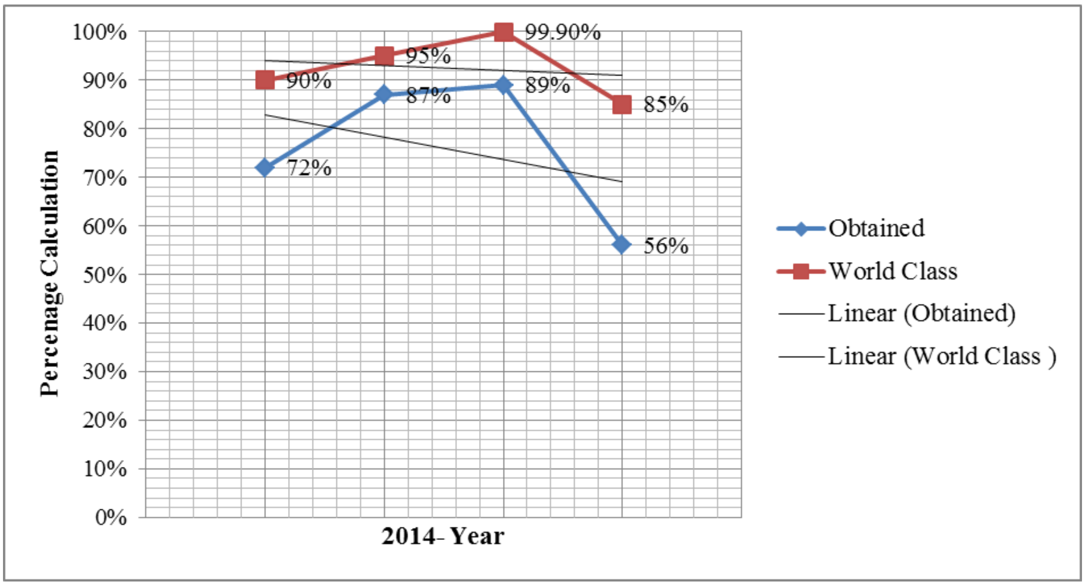

Fig 4.7: Comparison of OEE.

As per figure 4.7, it is clearly indicated that the Obtained OEE lies below the World Class OEE. According to world class OEE norms, the %Availability, %Performance, %Quality and %OEE are in 90%, 95%, 99.90%, and 85% respectively. As per the figure, it is observed that 72% Obtained Availability is not satisfying the World Class Availability is due to equipment breakdowns or failures and time for idle in terms of operators, materials, etc. Whereas 87% Performance is less than the required world-class norms for because of minor stoppage in terms of sensor blocked, misfeeds, jamming, rough running and reduced speed as compared desired speed. 89% quality losses are taken as filling factor or capacity losses as compared to world class quality norms. The Obtained OEE is much less than the benchmarking point of world class OEE as it occurs due to losses in down time, speed, filling factor.

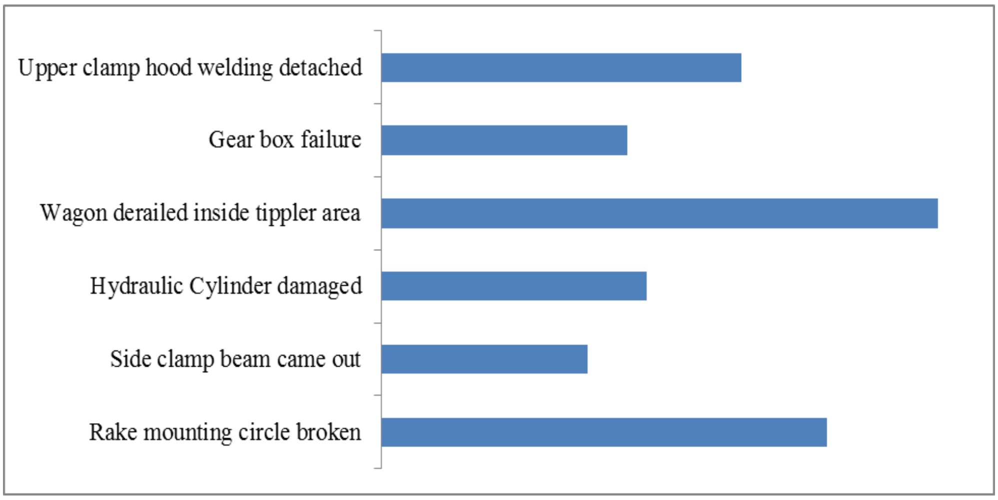

Fig 4.8: Analysis of Breakdown hour of Tippler equipment.

As per the proper analysis of Pie chart 4.1, it is investigated that the potential areas which lead to the unexpected breakdown of the machine. Figure 4.8 disclosss the loss of available hours for the breakdown of tippler is due to failure of upper clamp hood welding, gear box, derailment, hydraulic cylinder, side clamp beam and rake mounting circle. Among them, the highest breakdown hours occurs in wagon derailed inside tippler area.

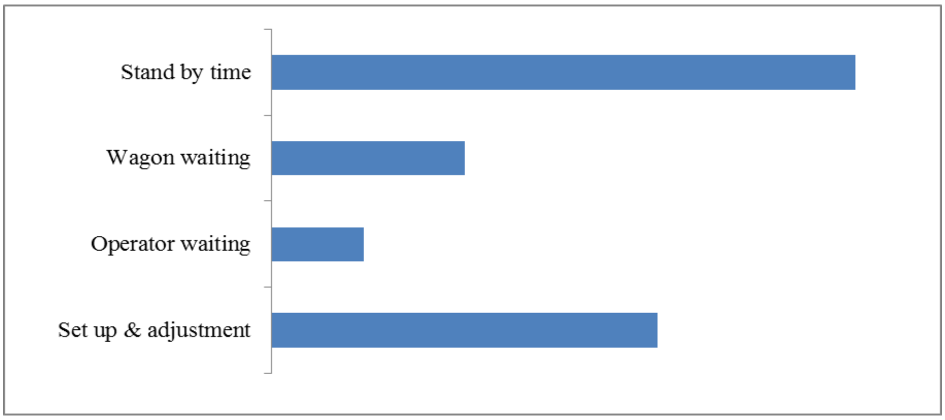

Fig 4.9: Analysis of Idle hour for Tippler equipment.

As per the proper analysis of Pie chart 4.1, it is investigated that the potential areas which lead to an unexpected idle time of the machine. Figure 4.9 disclosss the loss of available hours for idle of tippler is due to waiting for an operator, material, set up & adjust, etc.

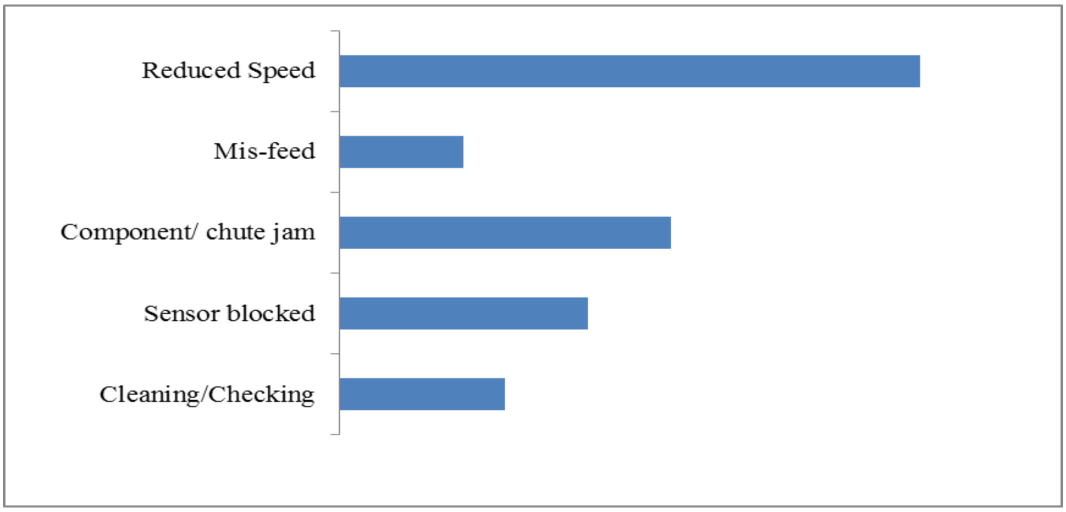

Fig 4.10: Analysis of Speed loss hour for Tippler equipment.

As per the proper analysis of Pie chart 4.1, it is investigated that the potential areas which lead to unexpected speed losses of the machine. Figure 4.10 discloses the loss of tippler speed is due to minor stoppage of equipment which is considered as less than five minutes for OEE calculation, for example, chute/component jamming, sensor blocked, misfeed, rough running, reduced equipment speed as compared to desired speed, cleaning/checking. Among them, the highest speed loss hours occur in reduced equipment speed as compared to theoretical maximum speed.

4.7 Comparison of World Class to Obtained OEE for Side Arm Charger

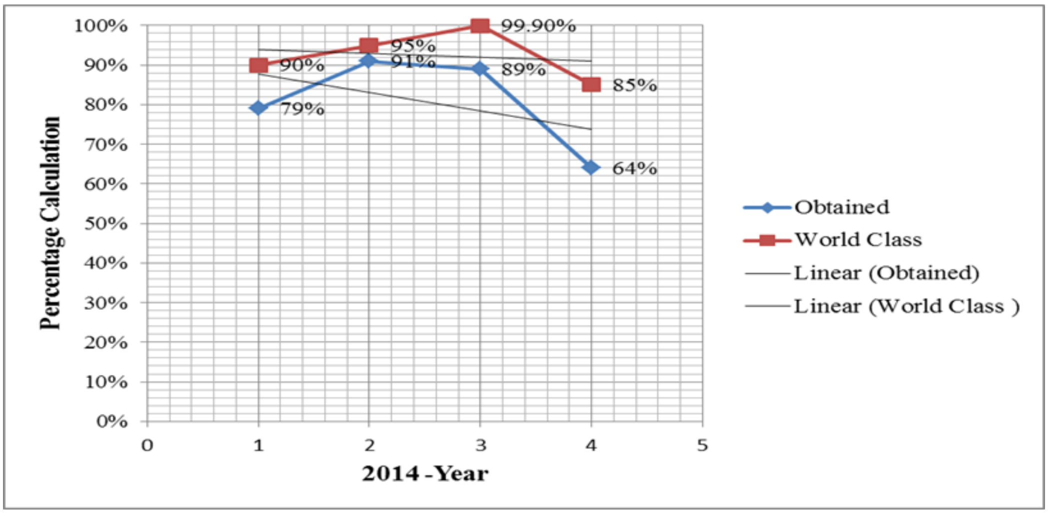

Fig 4.11: Comparison of OEE.

As per figure 4.11, it is clearly indicated that the obtained OEE lies below the world Class OEE. According to world class OEE norms, the %Availability, %Performance, %Quality and %OEE are in 90%, 95%, 99.90%, and 85% respectively. As per the figure, it is observed that 79% Obtained Availability is not satisfying the World Class Availability is due to equipment breakdowns or failures and time for idle in terms of operators, materials, etc. Whereas 91% Performance is less than the required world-class norms for because of minor stoppage in terms of sensor blocked, misfeeds, jamming, rough running and reduced speed as compared desired speed. 89% quality losses are taken as filling factor or capacity losses as compared to world class quality norms. The obtained OEE is much less than the benchmarking point of world class OEE as it occurs due to losses in down time, speed, filling factor.

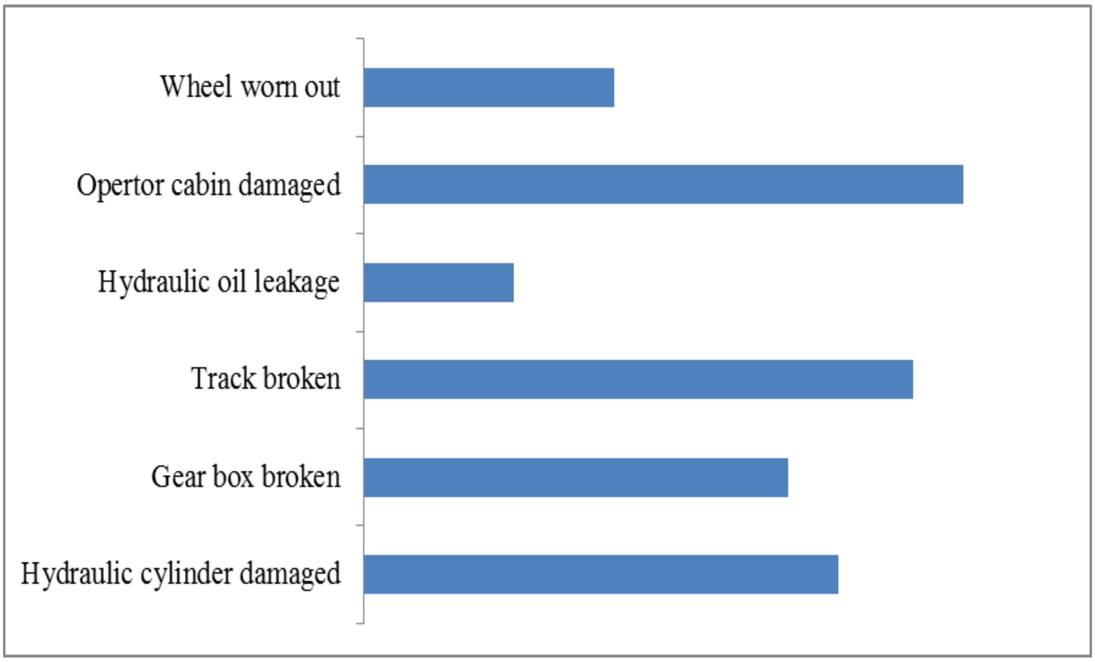

Fig 4.12: Analysis of Breakdown hour of Side Arm Charger equipment.

As per the proper analysis of Pie chart 4.2, it is investigated that the potential areas which lead to the unexpected breakdown of the machine. Figure 4.12 discloses the loss of available hours for breakdown of side arm charger is due to failure of the hydraulic cylinder, gearbox, rail track, hydraulic oil leakage, operator cabin, and wheel. Among them, the highest breakdown hours occurs in operator cabin whereas lowest in hydraulic oil leakage.

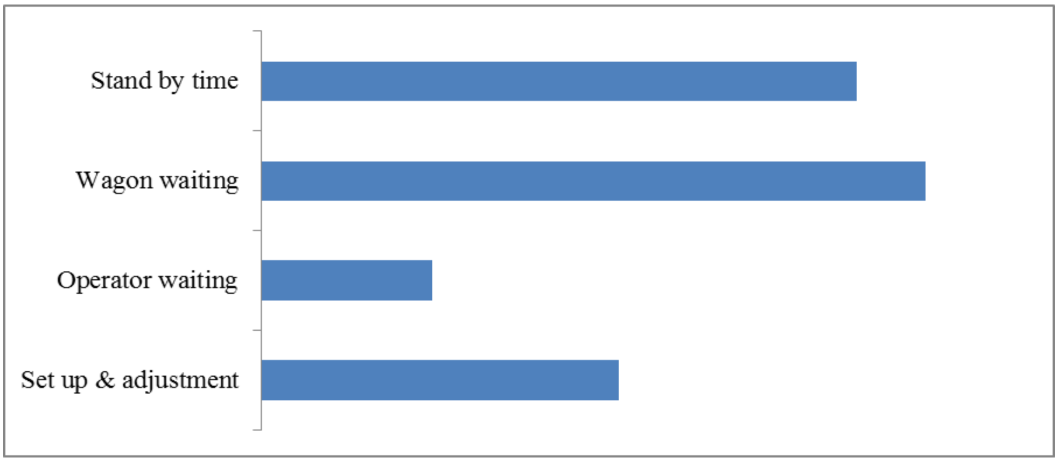

Fig 4.13: Analysis of Idle hour for Side Arm Charger equipment.

As per the proper analysis of Pie chart 4.2, it is investigated that the potential areas which lead to an unexpected idle time of the machine. Figure 4.13 discloses the loss of available hours for idle of side arm charger is due to waiting for an operator, material, set up & adjust, etc.

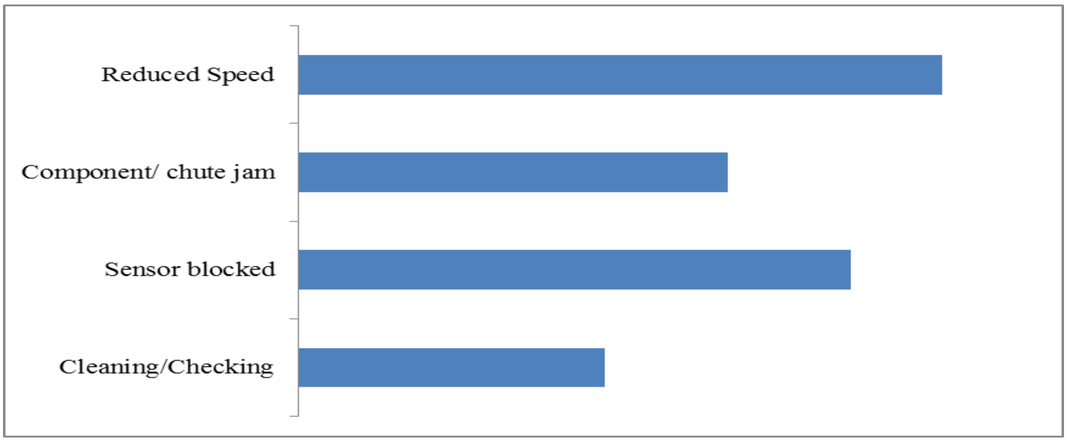

Fig 4.14: Analysis of Speed loss hour for Side arm charger equipment.

As per the proper analysis of Pie chart 4.2, it is investigated that the potential areas which lead to unexpected speed losses of the machine. Figure 4.14 discloses the loss of side arm charger speed is due to minor stoppage of equipment which is considered as less than five minutes for OEE calculation, for example, chute/component jamming, sensor blocked, misfeed, rough running, reduced equipment speed as compared desired speed, cleaning/checking. Among them, the highest speed loss hours occur in reduced equipment speed as compared to theoretical maximum speed.

4.8 Comparison of World Class to Obtained OEE for Reversible Apron Feeder

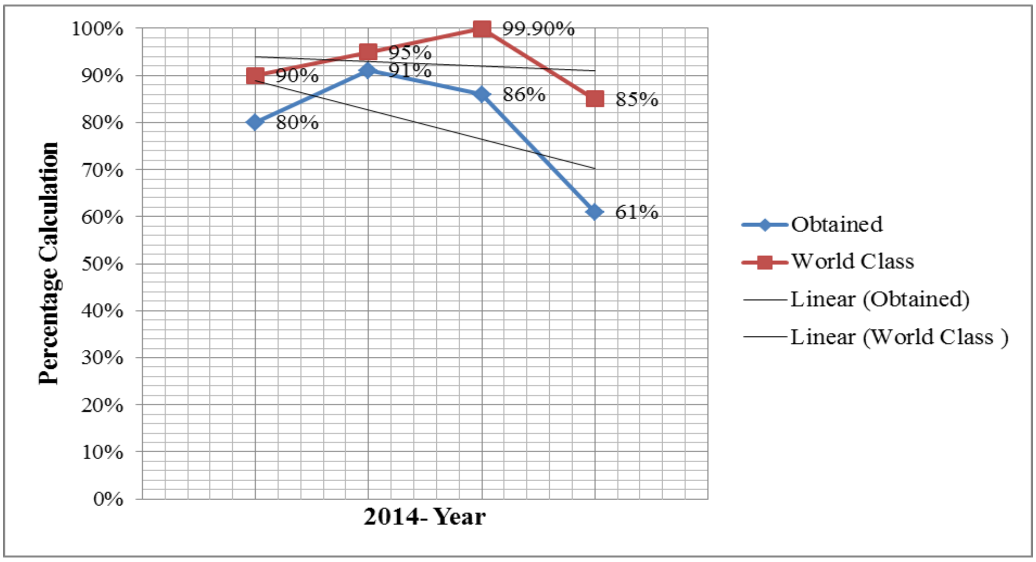

Fig 4.15: Comparison of OEE.

As per figure 4.15, it is clearly indicated that the obtained OEE lies below the world Class OEE. According to world class OEE norms, the %Availability, %Performance, %Quality and %OEE are in 90%, 95%, 99.90%, and 85% respectively. As per the figure, it is observed that 80% Obtained Availability is not satisfying the World Class Availability is due to equipment breakdowns or failures and time for idle in terms of operators, materials, etc. Whereas 91% Performance is less than the required world-class norms for because of minor stoppage in terms of sensor blocked, misfeeds, jamming, rough running and reduced speed as compared desired speed. 86% quality losses are taken as filling factor or capacity losses as compared to world class quality norms. The obtained OEE is much less than the benchmarking point of world class OEE as it occurs due to losses in down time, speed, filling factor.

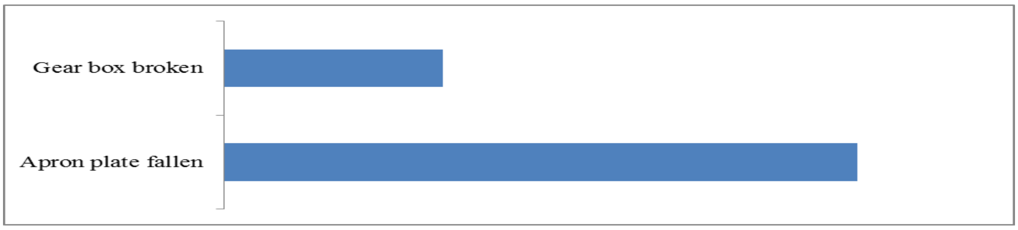

Fig 4.16: Analysis of Breakdown hour of Reversible Apron Feeder equipment.

As per the proper analysis of Pie chart 4.3, it is investigated that the potential areas which lead to the unexpected breakdown of the machine. Figure 4.16 discloses the loss of available hours for the breakdown of reversible apron feeder is due to failure gear box, apron plate. Among them, the highest breakdown hours occur in apron plate whereas lowest in gearbox.

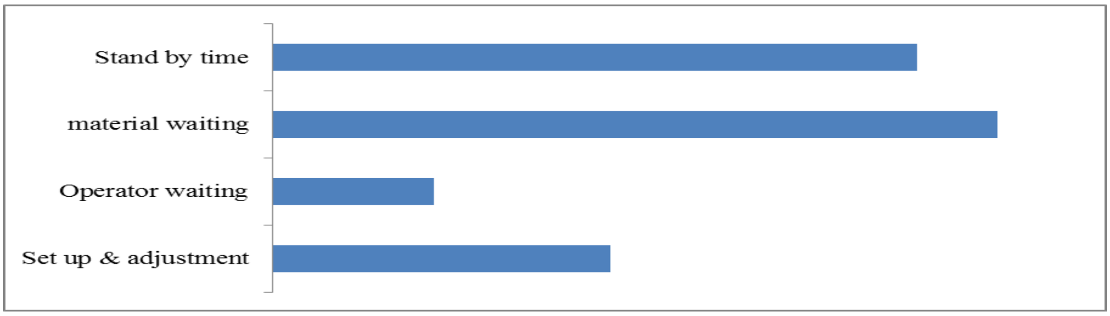

Fig 4.17: Analysis of Idle hour for Reversible Apron Feeder equipment.

As per the proper analysis of Pie chart 4.3, it is investigated that the potential areas which lead to an unexpected idle time of the machine. Figure 4.17 discloses the loss of available hours for idle of reversible apron feeder is due to waiting for an operator, material, set up & adjust, etc.

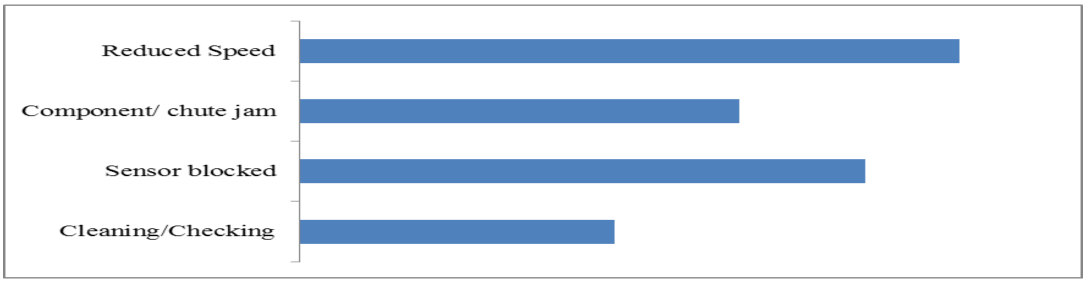

Fig 4.18: Analysis of Speed loss hour for Reversible Apron Feeder equipment.

As per the proper analysis of Pie chart 4.3, it is investigated that the potential areas which lead to unexpected speed losses of the machine. Figure 4.18 discloses the loss of reversible apron feeder speed is due to minor stoppage of equipment which is considered as less than five minutes for OEE calculation, for example, chute/component jamming, sensor blocked, misfeed, rough running, reduced equipment speed as compared desired speed, cleaning/checking. Among them, the highest speed loss hours occur in reduced equipment speed as compared to theoretical maximum speed.

4.9 Comparison of World Class to Obtained OEE for Belt Conveyor System

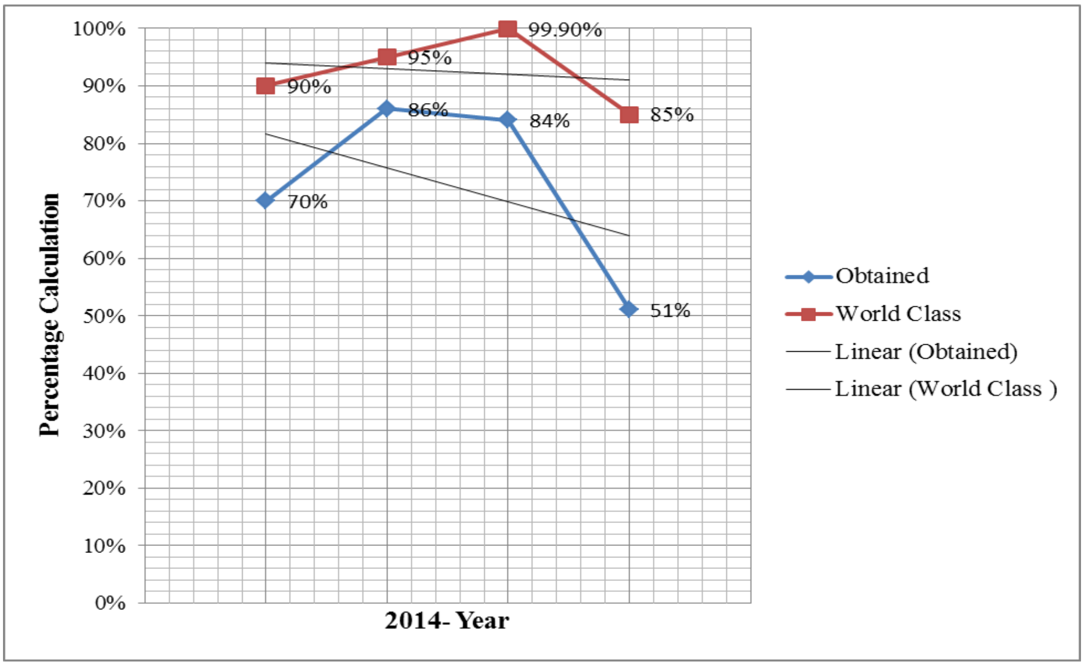

Fig 4.19: Comparison of OEE.

As per figure 4.19, it is clearly indicated that the Obtained OEE lies below the World Class OEE. According to world class OEE norms, the %Availability, %Performance, %Quality and %OEE are in 90%, 95%, 99.90%, and 85% respectively. As per the figure, it is observed that 70% Obtained Availability is not satisfying the World Class Availability is due to equipment breakdowns or failures and time for idle in terms of operators, materials, etc. Whereas 86% Performance is less than the required world-class norms for because of minor stoppage in terms of sensor blocked, misfeeds, jamming, rough running and reduced speed as compared desired speed. 84% quality losses are taken as filling factor or capacity losses as compared to world class quality norms. The Obtained OEE is much less than the benchmarking point of world class OEE as it occurs due to losses in down time, speed, filling factor.

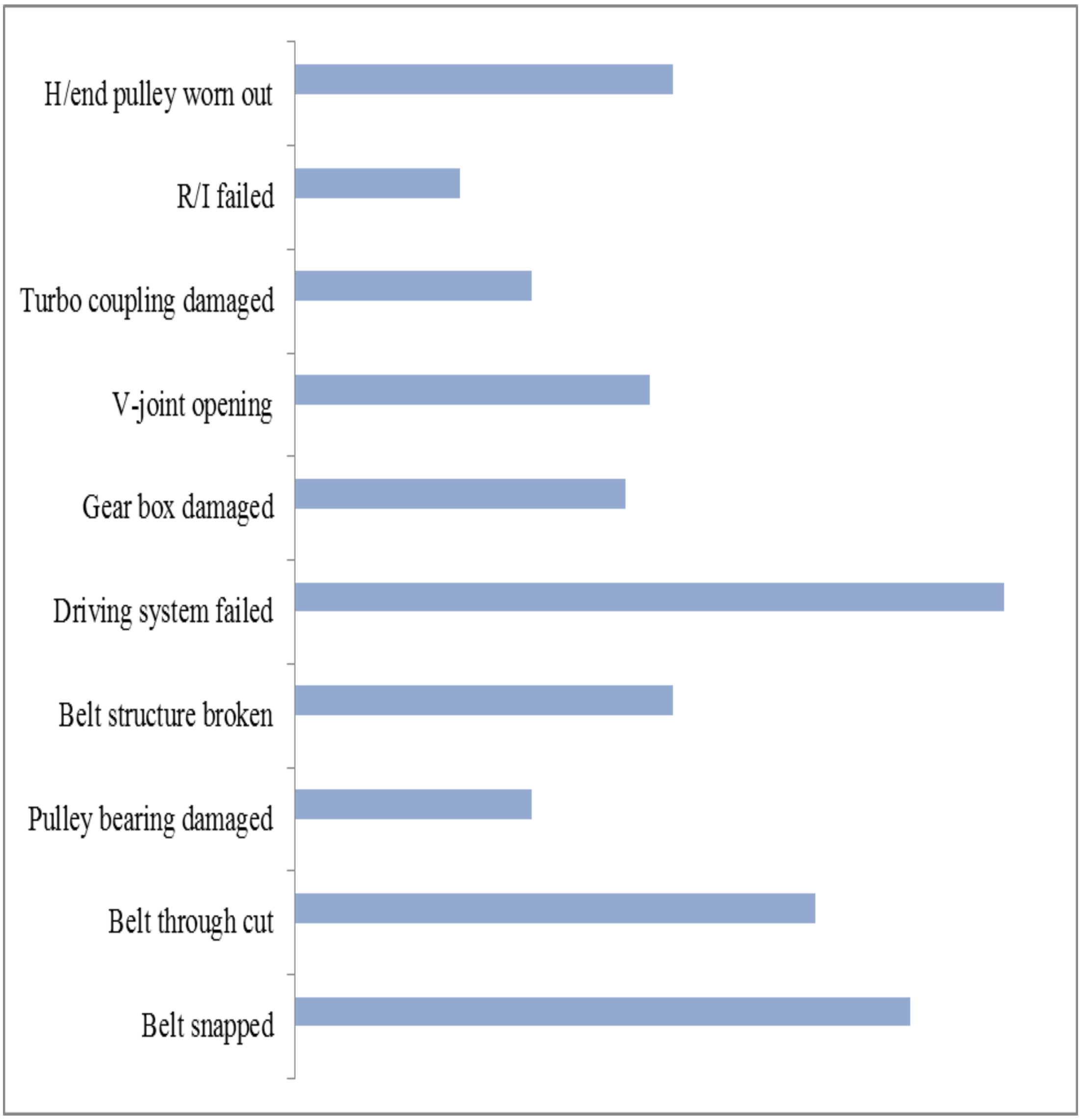

Fig 4.20: Analysis of Breakdown hour of Belt Conveyor System equipment.

As per the proper analysis of Pie chart 4.4, it is investigated that the potential areas which lead to the unexpected breakdown of the machine. Figure 4.20 shows the loss of available hours for the breakdown of belt conveyor system is due to failure of belt snapping, gear box, belt through cut, pulley bearing, belt structure and driving system, v-joint opening, turbo coupling, return idler, H/end pulley. Among them, the highest breakdown hours occur in a driving system where as lowest in return idler.

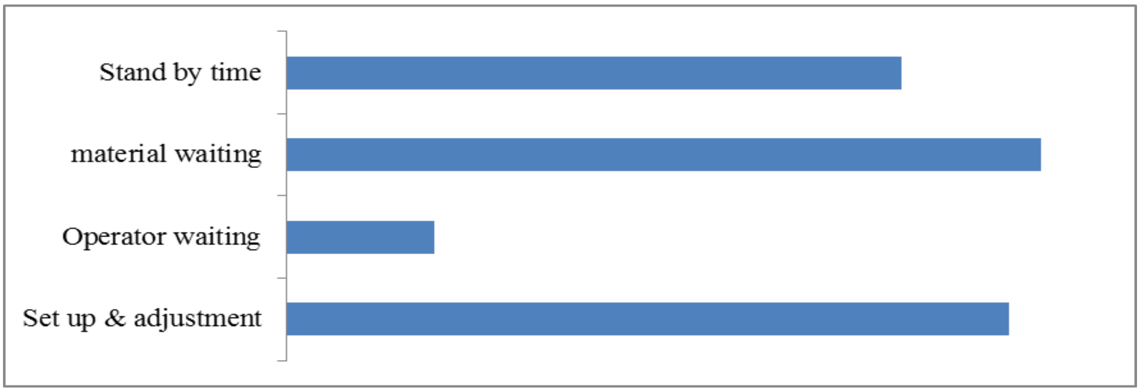

Fig 4.21: Analysis of Idle hour for Belt Conveyor System equipment.

As per the proper analysis of Pie chart 4.4, it is investigated that the potential areas which lead to an unexpected idle time of the machine. Figure 4.21 discloses the loss of available hours for idle of belt conveyor system is due to waiting for an operator, material, set up & adjust, etc.

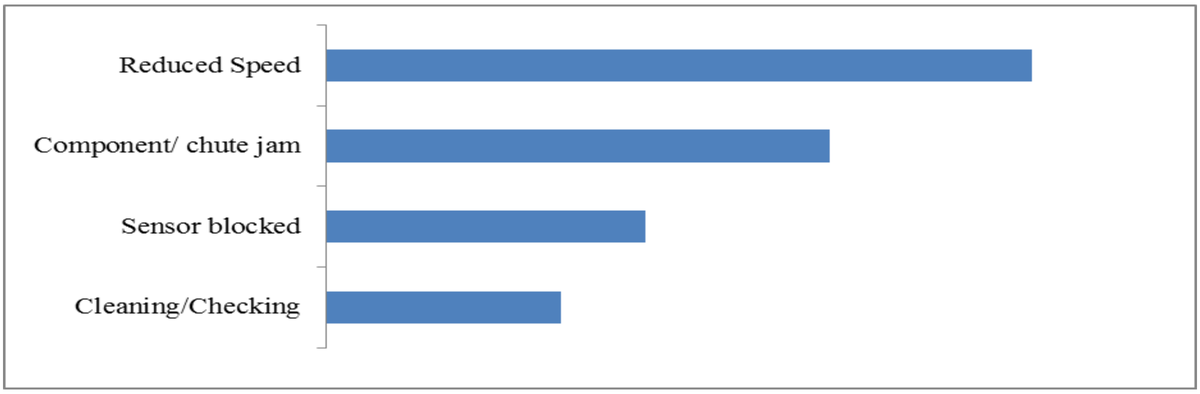

Fig 4.22: Analysis of Speed loss hour for Belt Conveyor System equipment.

As per the proper analysis of Pie chart 4.4, it is investigated that the potential areas which lead to unexpected speed losses of the machine. Figure 4.22 discloses the loss of belt conveyor speed is due to minor stoppage of equipment which is considered as less than five minutes for OEE calculation, for example, chute/component jamming, sensor blocked, misfeed, rough running, reduced equipment speed as compared desired speed, cleaning/checking. Among them, the highest speed loss hours occur in reduced equipment speed as compared to theoretical maximum speed.

4.10 Comparison of World Class to Obtained OEE for Stacker

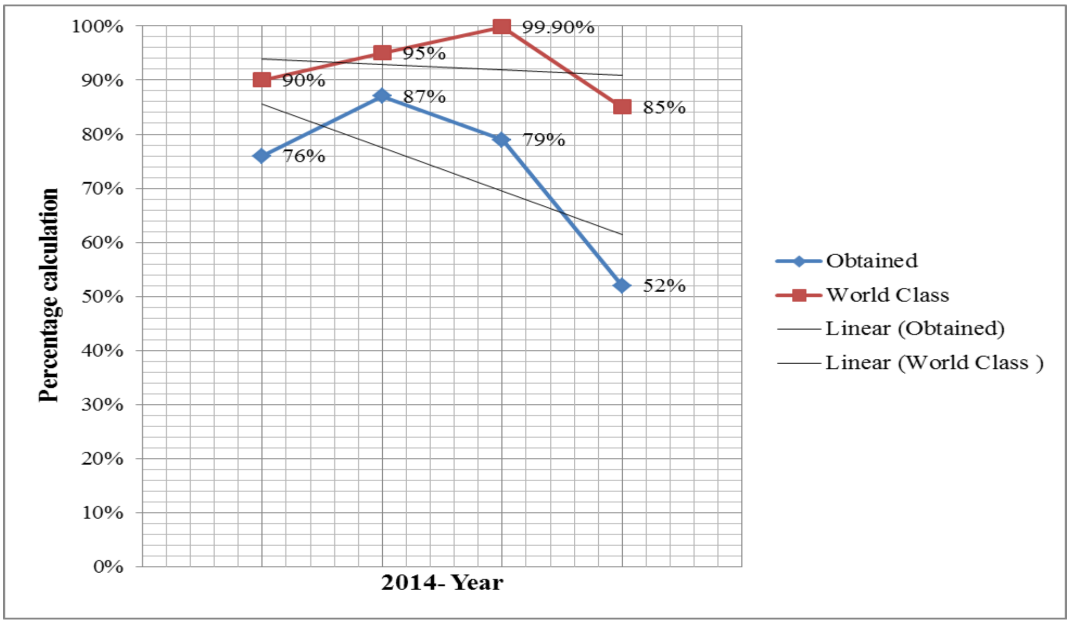

Fig 4.23: Comparison of OEE.

As per figure 4.23, it is clearly indicated that the Obtained OEE lies below the World Class OEE. According to world class OEE norms, the %Availability, %Performance, %Quality and %OEE are in 90%, 95%, 99.90%, and 85% respectively. As per the figure, it is observed that 76% Obtained Availability is not satisfying the World Class Availability is due to equipment breakdowns or failures and time for idle in terms of operators, materials, etc. Whereas 87% Performance is less than the required world class norms for because of minor stoppage in terms of sensor blocked, misfeeds, jamming, rough running and reduced speed as compared desired speed. 79% quality losses are taken as filling factor or capacity losses as compared to world class quality norms. The Obtained OEE is much less than the benchmarking point of world class OEE as it occurs due to losses in down time, speed, filling factor.

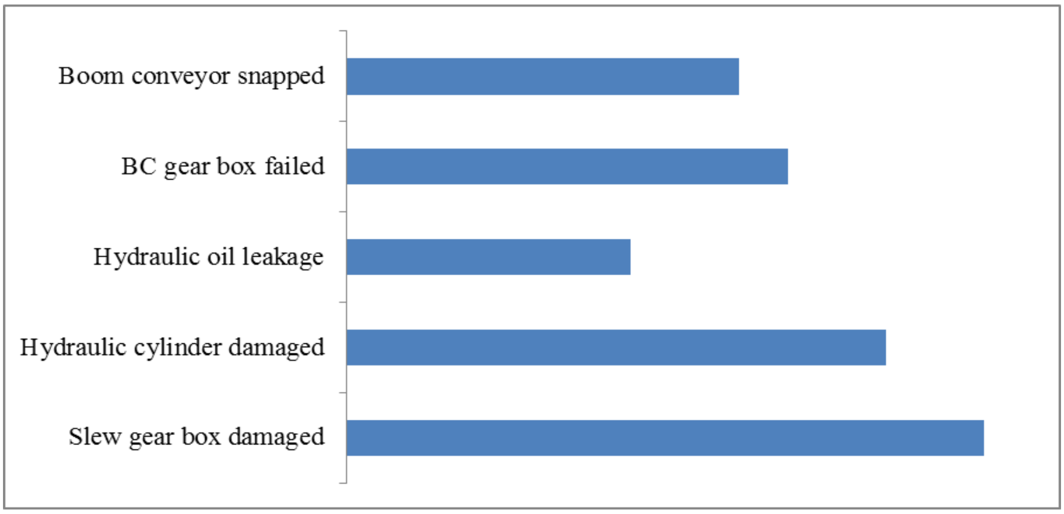

Fig 4.24: Analysis of Breakdown hour of Stacker equipment.

As per the proper analysis of Pie chart 4.5, it is investigated that the potential areas which lead to the unexpected breakdown of the machine. Figure 4.24 discloses the loss of available hours for the breakdown of the stacker is due to failure of boom conveyor, boom conveyor gear box, hydraulic oil leakage, hydraulic cylinder, slew gear box. Among them, the highest breakdown hours occur in slew gearbox whereas lowest in oil leakage in the hydraulic cylinder.

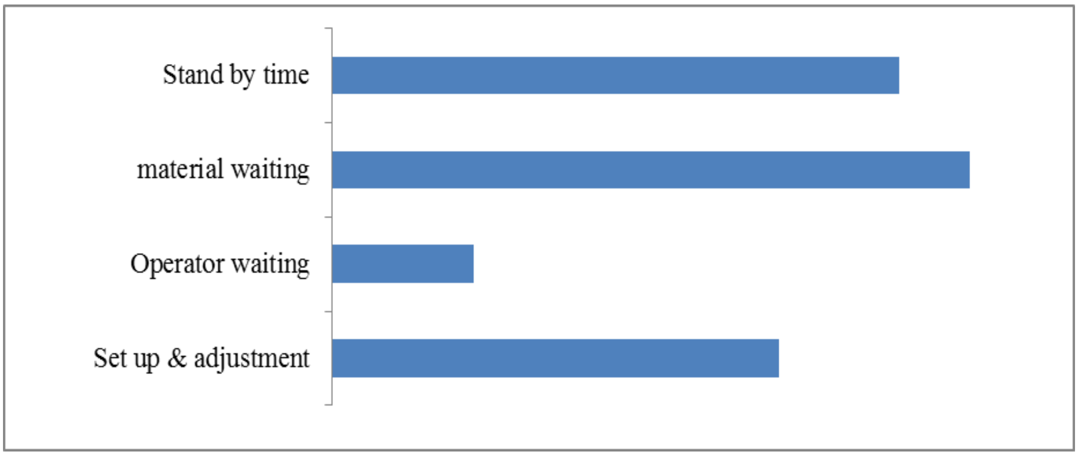

Fig 4.25: Analysis of Idle hour for Stacker equipment.

As per the proper analysis of Pie chart 4.5, it is investigated that the potential areas which lead to an unexpected idle time of the machine. Figure 4.25 discloses the loss of available hours for idle of the stacker is due to waiting for operators, material, set up & adjust, etc.

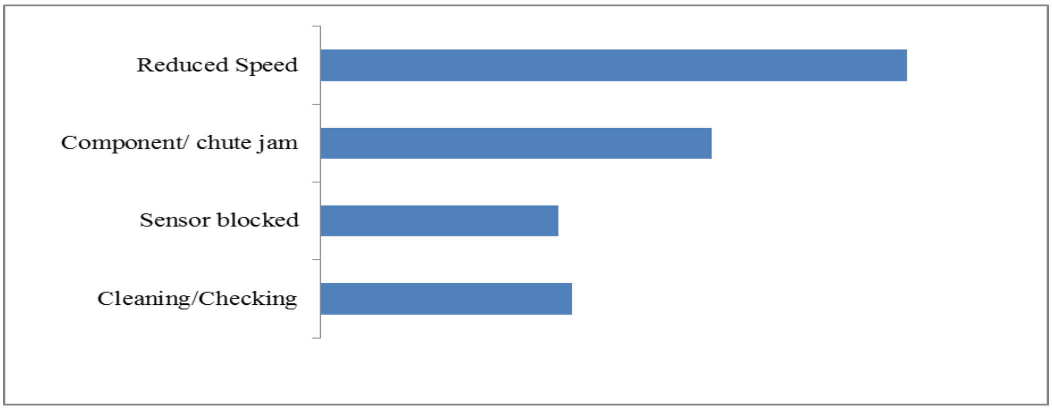

Fig 4.26: Analysis of Speed loss hour for Stacker equipment.

As per the proper analysis of Pie chart 4.5, it is investigated that the potential areas which lead to unexpected speed losses of the machine. Figure 4.26 discloses that the loss of stacker is due to minor stoppage of equipment which is considered as less than five minutes for OEE calculation, for example, chute/component jamming, sensor blocked, misfeed, rough running, reduced equipment speed as compared desired speed, cleaning/checking. Among them, the highest speed loss hours occur in reduced equipment speed as compared to theoretical maximum speed.

4.11 Comparison of World Class to Obtained OEE for Reclaimer

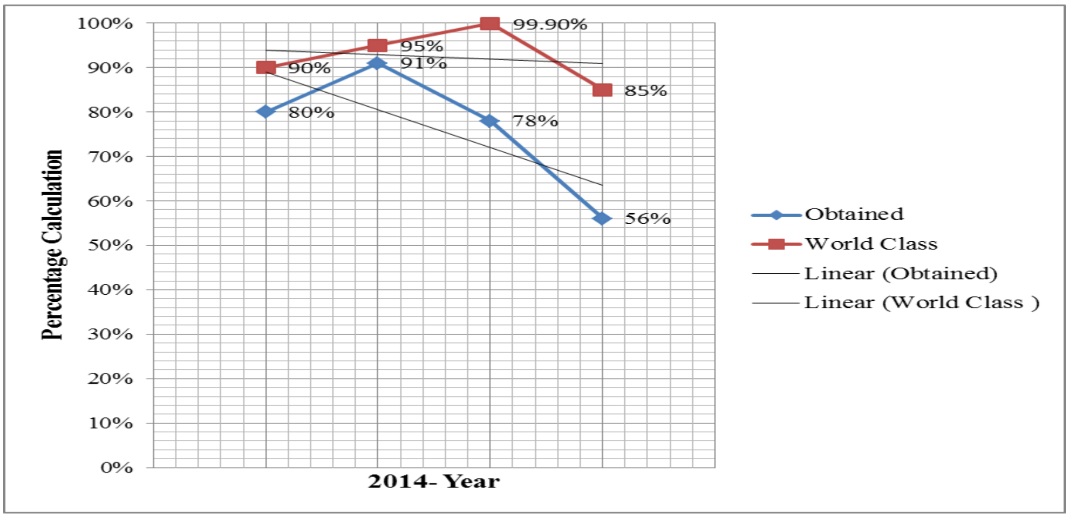

Fig 4.27: Comparison of OEE.

As per figure 4.27, it is clearly indicated that the Obtained OEE lies below the World Class OEE. According to world class OEE norms, the %Availability, %Performance, %Quality and %OEE are in 90%, 95%, 99.90%, and 85% respectively. As per the figure, it is observed that 80% Obtained Availability is not satisfying the World Class Availability is due to equipment breakdowns or failures and time for idle in terms of operators, materials, etc. Whereas 91% Performance is less than the required world-class norms for because of minor stoppage in terms of sensor blocked, misfeeds, jamming, rough running and reduced speed as compared desired speed. 78% quality losses are taken as filling factor or capacity losses as compared to world class quality norms. The Obtained OEE is much less than the benchmarking point of world class OEE as it occurs due to losses in down time, speed, filling factor.

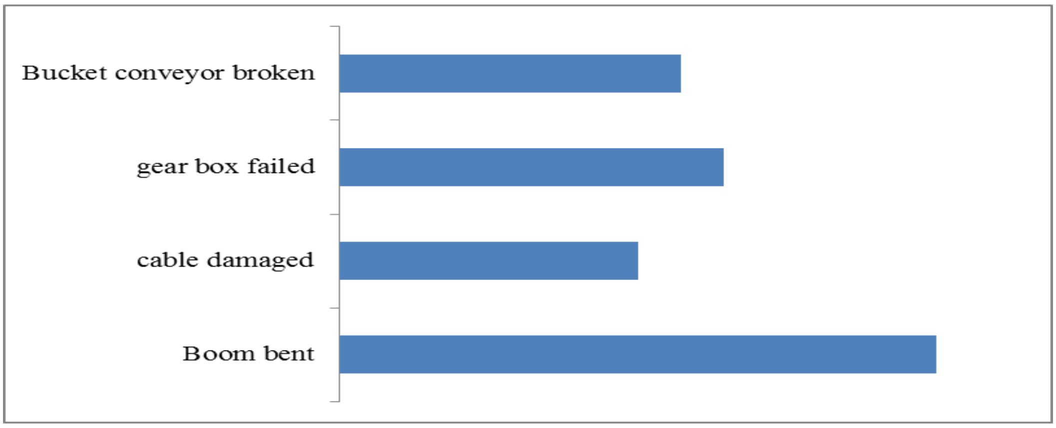

Fig 4.28: Analysis of Breakdown hour of Reclaimer equipment.

As per the proper analysis of Pie chart 4.6, it is investigated that the potential areas which lead to the unexpected breakdown of the machine. Figure 4.28 discloses the loss of available hours for the breakdown of reclaimer is due to failure of boom conveyor, boom conveyor gear box, hydraulic oil leakage, hydraulic cylinder, slew gear box. Among them, the highest breakdown hours occurs in boom bent whereas lowest in cable failure.

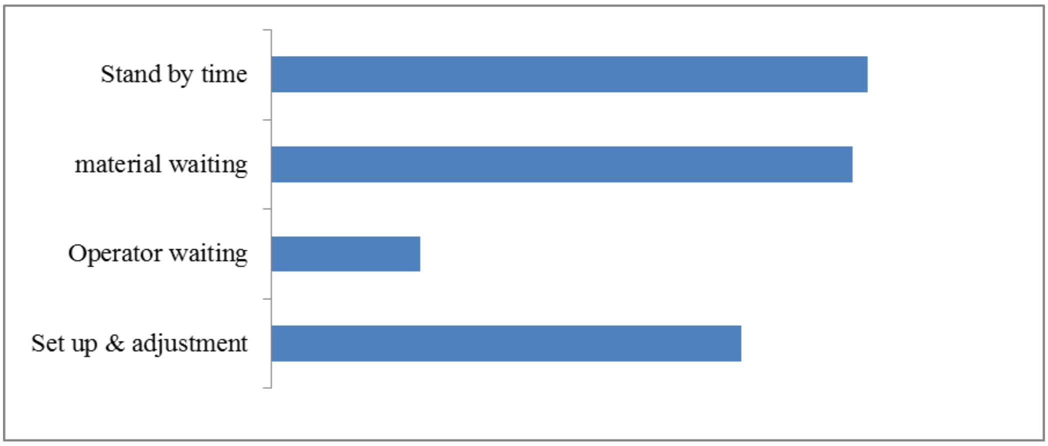

Fig 4.29: Analysis of Idle hour for Reclaimer equipment.

As per the proper analysis of Pie chart 4.6, it is investigated that the potential areas which lead to an unexpected idle time of the machine. Figure 4.29 discloses the loss of available hours for idle of reclaimer is due to waiting for operators, material, set up & adjust, etc.

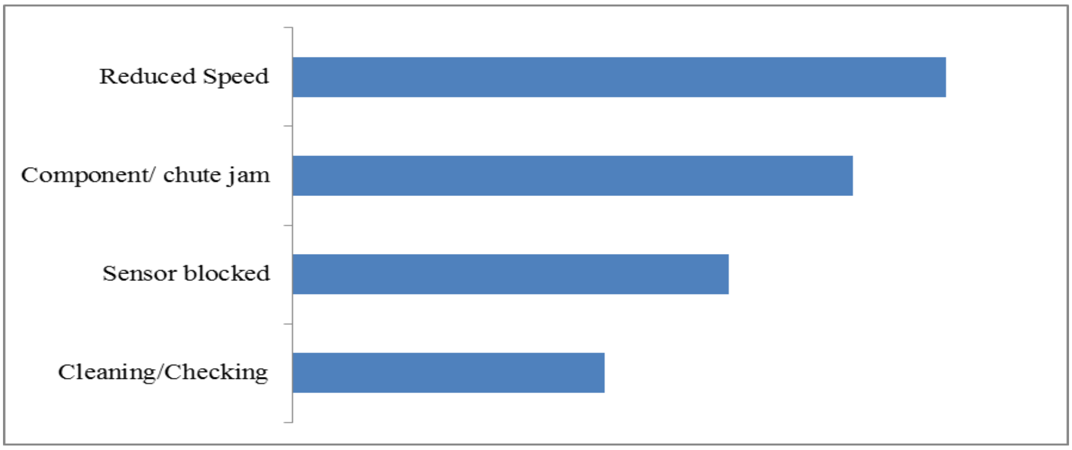

Fig 4.30: Analysis of Speed loss hour for Reclaimer equipment.

As per the proper analysis of Pie chart 4.6, it is investigated that the potential areas which lead to unexpected speed losses of the machine. Figure 4.30 discloses the loss of reclaimer is due to minor stoppage of equipment which is considered as less than five minutes for OEE calculation, for example, chute/component jamming, sensor blocked, misfeed, rough running, reduced equipment speed as compared desired speed, cleaning/checking. Among them, the highest speed loss hours occur in reduced equipment speed as compared to theoretical maximum speed.

4.12 Comparison of parameters with their calculations of different equipment in Coal Handling Plant for OEE obtained & world class.

Table 4.15: Comparison of a parameter of coal handling equipment.

Calculation Parameter	**Tippler**	**SAC**	**RAF**	**BCS**	**Stacker**	**Reclaimer**	**Avg. Obtained**	**World class**
Availability	**72%**	**79%**	**80%**	**70%**	**76%**	**80%**	**76%**	**90%**
Performance	**87%**	**91%**	**91%**	**86%**	**87%**	**91%**	**89%**	**95%**
Quality	**89%**	**89%**	**86%**	**84%**	**79%**	**78%**	**84%**	**99.9%**
OEE	**54%**	**64%**	**61%**	**51%**	**52%**	**56%**	**57%**	**85%**

The above table shows the different equipment are Tippler, SAC- Side arm charger, RAF- Reversible apron feeder, BCS- Belt conveyor system, Stacker, Reclaimer with its availability in 72%, 79%, 80%, 70%, 76%, 80% respectively. The average availability is 76% which is less than world class availability where as 89% average performance obtained which is also less than required norms and 84% for Quality lies below the world class quality.

The OEE obtained for the above equipment in systematic order in 54%, 64%, 61%, 51%, 52%, 56% respectively. The average obtained OEE 57% in coal handling plant is much less than the world-class norms.

Therefore, it is necessary for the improvement of coal handling plant that some suitable methodology as an outcome of OEE be adopted for output maximization and labour cost decrease.

4.13 Summery

This chapter broadly divided into three parts. The first part fully describes the theory of OEE and Six big losses with event examples. The second part calculates OEE with their time losses of coal handling equipment. The third part provides the comparison chart of World class to Obtained OEE. The purpose of this chapter is to provide a brief idea about time loss classifications for performance measurement of equipment by OEE. The calculation of OEE is presented through table considering the operational losses in coal handling equipment viz. Tippler, Side arm charger, Reversible apron feeder, Belt conveyor, Stacker, Reclaimer. This chapter also presents the performance report of coal handling equipment through pie chart and analyzes briefly about their data for production losses. This chapter also compares the World class OEE to Obtained OEE and their parameters with calculations of different equipment in coal handling plant.

Chapter 5

SUGGESTION, RESULT & DISCUSSION

5.1 Overview

In the last few decades, industries were forced to shift their business models from closed system-orientations to more open system-orientations. This shift was brought about by drastic competitive forces, which made the customer the focus of the organizational, operational & strategic practices. Today's industries are required to operate as operational systems with the increasing complexity, scope and organizational role of operationally advanced industry technologies the maintenance of these technologies is becoming very critical to the ability of the organization to complete.

Every company wants to achieve high targets and long term profits. Organisations with successful quality improvement program can enjoy significant competitive advantages. In coal handling industries, availability of equipment is the vital role for production gain. More and more techniques are developed for inspection of plant equipment. Increasing automation and mechanization production processes are shifting from workers to machine dependent. Consequently, the plant production depends on the operational maintenance in controlling quantity, quality and cost is more evident and important than ever. To succeed in this new environment, equipment must be maintained in ideal operating conditions & must run effectively. The inspections of equipment in right method results in operational gain and promote productivity. The thought behind the implementation of this methodology in coal handling companies is to get everyone more involved and all companies answered that they are succeeded with that. The implementation has also gained a positive process progress in both economical and quality aspect, and also work environment has been better as improvements from the employees and the new layout of the factories have been implemented.

5.2 Methodology for determining the status of Tippler: Parameters, aspects, and technology.

Table 5.1: Methodology for determining the status of Tippler.

Parameter	**Component**	**Sensor/Technology**
Vibration	Motor Gear Box	Vibration analyzer Instrument
Power	Motor	Watt meter Torque Sensor
Speed	Motor Tippler Rotating Drive/ Brake system component	Optical/ Magnetic encoder Magnetic RPM picks up sensor
Temperature	Motor Material Hydraulic Oil	Thermocouple Infrared temperature sensor
Pressure	Hydraulic Oil	Pressure gauge
Shock	Gear Box Coupling (Revolving element like ball & roller bearing)	Shock pulse meter
Minor Crack	All accessories in Tippler	Ultrasonic flaw detector
Foundation Columns	All accessories in Tippler	Mechanical or electrical strain gauge
Hotspot	Bearing Other parts of machinery	Infra-red thermometer Remote sensing
Thickness of paint, coating	Hood Channel	Ultrasonic/ Eddy Current thickness meter
Corrosion	Tippler equipment like hood, beam, structure etc...	Corrosion meter
Leakage	Oil at high pressure	Ultrasonic Leak Detector

5.2.1 Result & Discussion of Tippler

After implementing this methodology in coal handling plant of tippler section, it is found that the overall equipment effectiveness is maximized by 10% (Refer Fig. 5.1). This methodology helps to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours (Refer Fig. 5.2) was also minimized as a result, in turn, decrease of throughput time. On the basis of proper study and analysis of the OEE before and after implementation, it has been shown that a remarkable growth, which is an indication of an increase in equipment availability, performance, and quality.

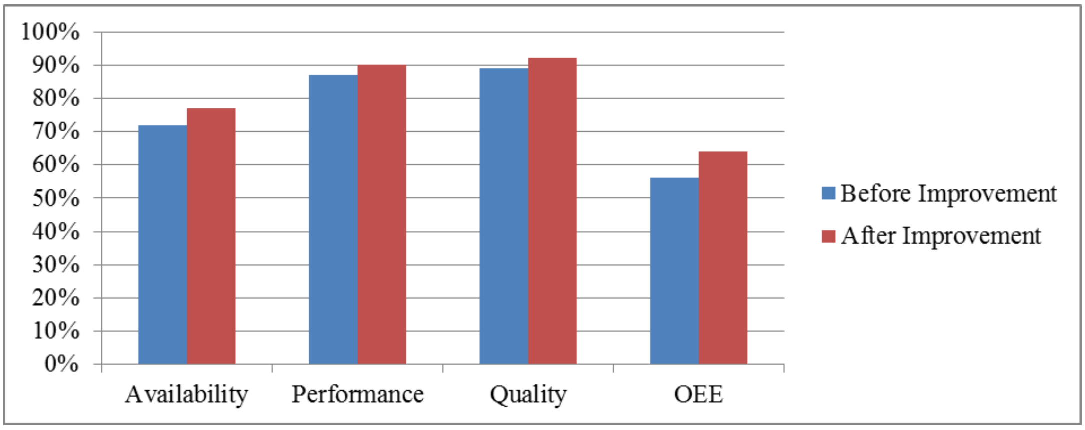

Fig 5.1: Comparison of OEE its factor Before & After Improvement.

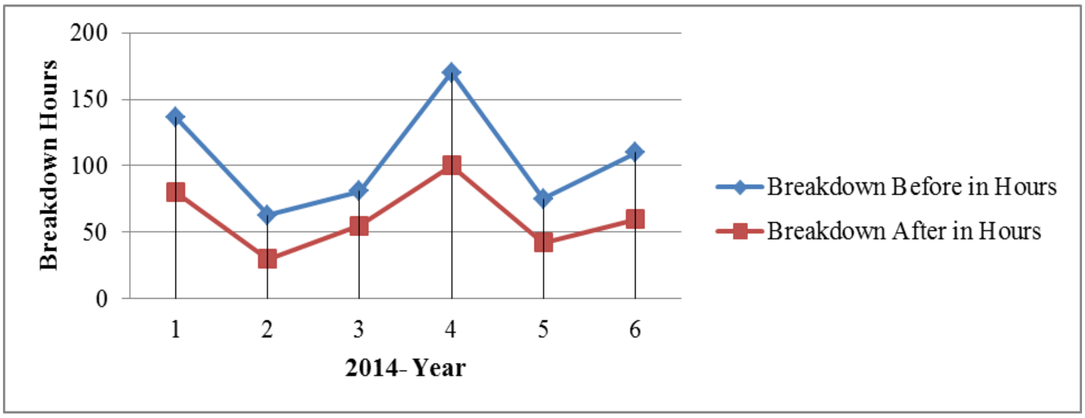

Fig 5.2: Comparison of Breakdown Hours Before & After Improvement.

5.3 Methodology for determining the status of Side Arm Charger: Parameters, aspects, and technology

Table 5.2: Methodology for determining the status of Side arm charger.

Parameter	Component	Sensor/Technology
Vibration	Hydraulic Motor	Vibration analyzer Instrument
Power	Hydraulic Motor	Watt meter Torque Sensor
Speed	Hydraulic Motor/ SAC Drive	Optical/ Magnetic encoder Magnetic RPM pickup sensor
Temperature	Hydraulic Motor Material Hydraulic Oil	Thermocouple Infrared temperature sensor
Pressure	Hydraulic Oil	Pressure switch (sensor)
Shock	Gear Box Coupling (Revolving element like ball & roller bearing)	Shock pulse meter
Minor Crack	All accessories in SAC	Ultrasonic flaw detector
Foundation	Side arm charger	Mechanical or electrical strain gauge
Hotspot	Bearing Other parts of machinery	Infra-red thermometer Remote sensing
Corrosion	SAC equipment like arm, coupler, structure etc...	Corrosion meter
Leakage	Hyd. Oil at high pressure	Ultrasonic Leak Detector
Position	Side Arm Charger	Proximity switch
Over travel	Side Arm Charger	End limit switch

5.3.1 Result & Discussion of Side Arm Charger

After implementing this methodology in coal handling plant of side arm charger, it is found that the overall equipment effectiveness is maximized by 4% (Refer Fig. 5.3). This methodology helps to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours (Refer Fig. 5.4) was also minimized as a result, in turn, decrease of throughput time. On the basis of proper study and analysis of the OEE before and after implementation, it has been shown that a remarkable growth, which is an indication of an increase in equipment availability, performance, and quality.

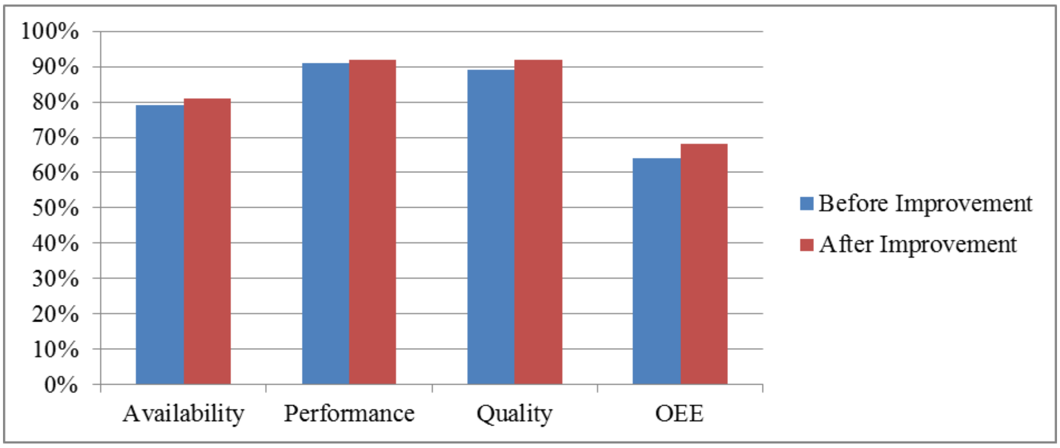

Fig 5.3: Comparison of OEE its factor Before & After Improvement.

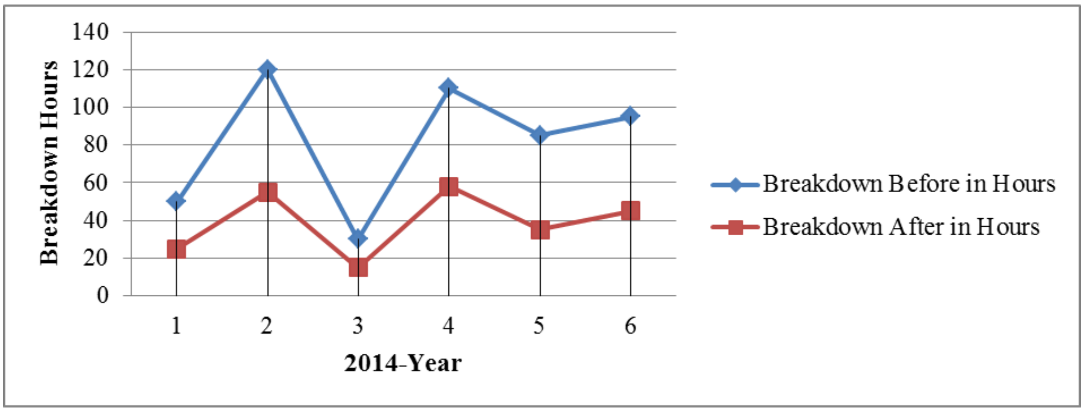

Fig 5.4: Comparison of Breakdown Hours Before & After Improvement.

5.4 Methodology for determining the status of Reversible Apron Feeder: Parameters, aspects, and technology

Table 5.3: Methodology for determining the status of Reversible apron feeder.

Parameter	**Component**	**Sensor/Technology**
RAF Condition	Surface Apron plate	Visual detection
Vibration	Motor Gear Box	Vibration analyzer Instrument
Power	Motor	Watt meter Torque Sensor
Speed	Motor	Optical/ Magnetic encoder Magnetic RPM pick up sensor
Temperature	Motor Material Lube oil	Thermocouple Infrared temperature sensor
Torque	Motor shaft	Torque meter
Force & Tension	Frame	Strain gauge
Pressure	Hydraulic Oil	Pressure gauge
Shock	Gear Box Coupling (Revolving element like ball & roller bearing)	Shock pulse meter
Minor Crack	All accessories in RAF	Ultrasonic flaw detector
Foundation Columns	All accessories in RAF	Mechanical or electrical strain gauge
Hotspot	Bearing Other parts of machinery	Infra-red thermometer Remote sensing
Thickness of paint, coating	Channel	Ultrasonic/ Eddy Current thickness meter
Corrosion	RAF equipment like wearing plate, apron plate, structure etc...	Corrosion meter
Apron plate falls	Reversible Apron Feeder	Limit switch

5.4.1 Result & Discussion of Reversible Apron Feeder

After implementing this methodology in coal handling plant of reversible apron feeder equipment, it is found that the overall equipment effectiveness is maximized by 7% (Refer Fig. 5.5). This methodology helps to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours (Refer Fig. 5.6) was also minimized as a result, in turn, decrease of throughput time. On the basis of proper study and analysis of the OEE before and after implementation, it has been shown that a remarkable growth, which is an indication of an increase in equipment availability, performance, and quality.

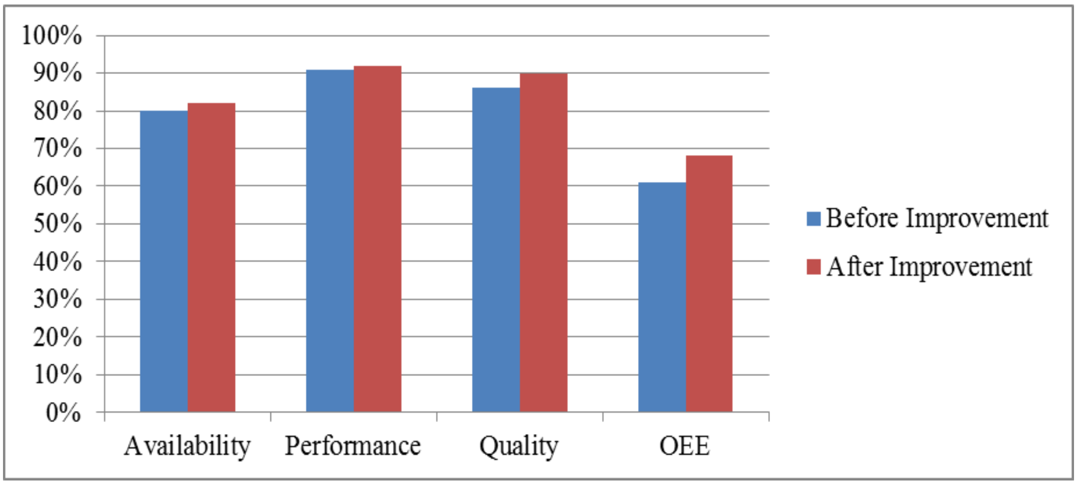

Fig 5.5: Comparison of OEE its factor Before & After Improvement.

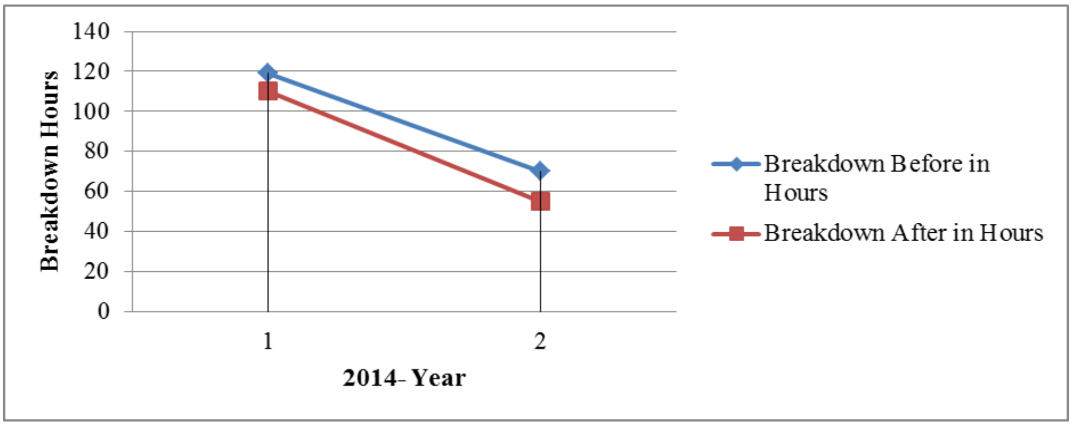

Fig 5.6: Comparison of Breakdown Hours Before & After Improvement.

5.5 Methodology for determining the status of Belt conveyor system: Parameters, aspects, and technology.

Table 5.4: Methodology for determining the status of Belt conveyor system.

Parameter	Component	Sensor/Technology
Belt Condition	Surface Steel cables	Visual detection Conductive detection
Vibration	Pulley Idler roller Motor Gear Box	Acoustic vibration sensor Accelerometer Vibration analyzer Instrument
Power	Motor	Watt meter Torque Sensor
Speed	Motor Brake disk Belt	Optical/ Magnetic encoder Magnetic RPM picks up sensor
Temperature	Ambient Material Brake disk Belt cover Pulley shaft Motor	Thermocouple Infrared temperature sensor
Torque	Motor shaft Brake shaft Pulley shaft	Torque meter
Position	Belt misalignment Take-up displacement	Alignment switch Optical encoder
Shock	Gear Box Coupling (Revolving element like ball & roller bearing)	Shock pulse meter
Minor Crack	All accessories in BCS	Ultrasonic flaw detector
Foundation Columns	All accessories in BCS	Mechanical or electrical strain gauge
Hotspot	Bearing Other parts of machinery	Infra-red thermometer Remote sensing
Thickness of paint, coating	Structure Channel Belt conveyor	Ultrasonic/ Eddy Current thickness meter
Corrosion	BCS equipment like structure, idler stand, channel etc...	Corrosion meter

5.5.1 Result & Discussion of Belt Conveyor System

After implementing this methodology in coal handling plant of belt conveyor system, it is found that the overall equipment effectiveness is maximized by 10% (Refer Fig. 5.7). This methodology helps to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours (Refer Fig. 5.8) was also minimized as a result, in turn, decrease of throughput time. On the basis of proper study and analysis of the OEE before and after implementation, it has been shown that a remarkable growth, which is an indication of an increase in equipment availability, performance, and quality.

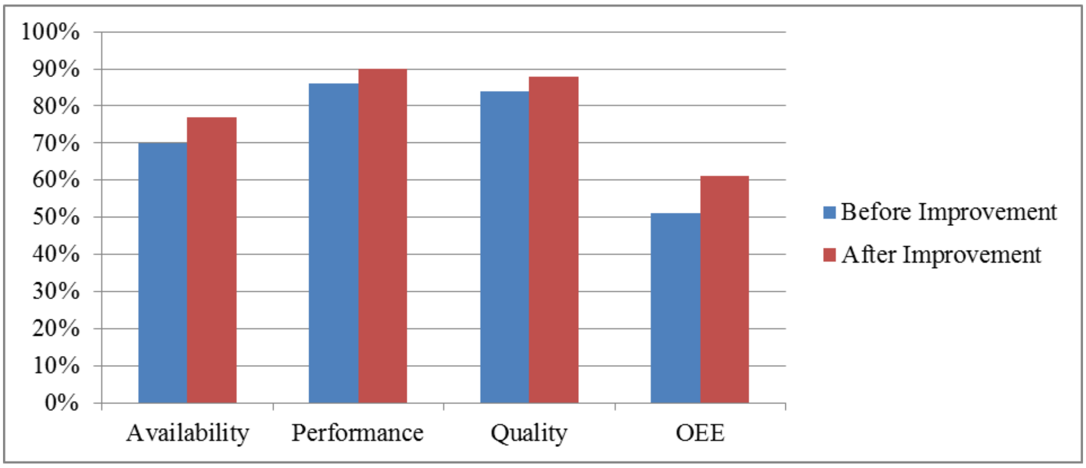

Fig 5.7: Comparison of OEE its factor Before & After Improvement.

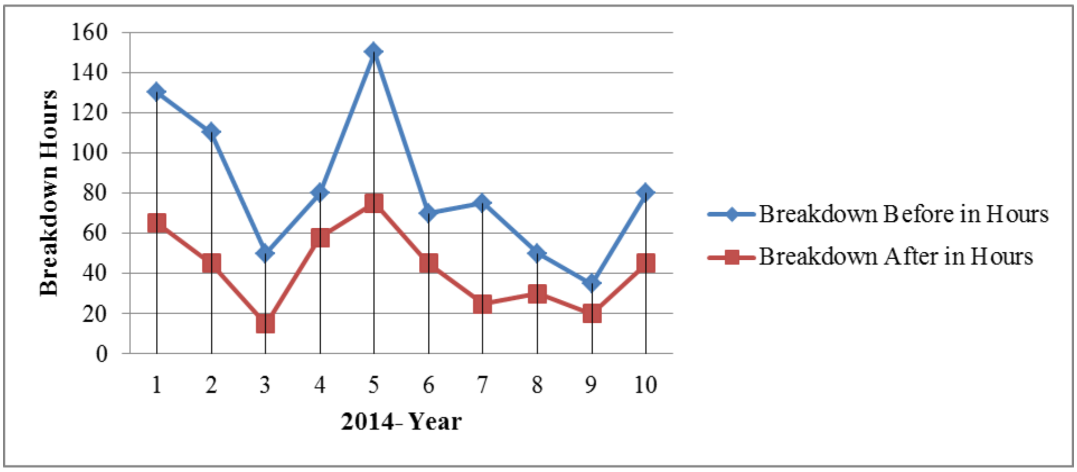

Fig 5.8: Comparison of Breakdown Hours Before & After Improvement.

5.6 Methodology for determining the status of Stacker: Parameters, aspects, and technology.

Table 5.5: Methodology for determining the status of Stacker.

Parameter	Component	Sensor/Technology
Vibration	Pulley Motor Gear Box	Acoustic vibration sensor Accelerometer Vibration analyzer Instrument
Power	Motor	Watt meter Torque Sensor
Speed	Motor Boom conveyor Main travel gearbox	Optical/ Magnetic encoder Magnetic RPM pick up sensor
Temperature	Material Gear Box Boom conveyor cover Pulley shaft Motor Hydraulic oil	Thermocouple Infrared temperature sensor
Torque	Motor shaft Brake shaft Pulley shaft	Torque meter
Force & Tension	Pulley Boom conveyor Frame	Strain gauge
Position	Belt misalignment Take-up displacement	Alignment switch Optical encoder
Pressure	Hydraulic oil Lubrication oil	Pressure gauge
Shock	Gear Box Coupling (Revolving element like ball & roller bearing)	Shock pulse meter
Minor Crack	All accessories in Stacker	Ultrasonic flaw detector
Hotspot	Bearing Other parts of machinery	Infra-red thermometer Remote sensing
Thickness of paint, coating	Structure and its component	Ultrasonic/ Eddy Current thickness meter
Corrosion	Stacker equipment like, beam, structure etc.	Corrosion meter
Leakage	Oil at high pressure	Ultrasonic Leak Detector

5.6.1 Result & Discussion of Stacker

After implementing this methodology in coal handling plant of stacker section, it is found that the overall equipment effectiveness is maximized by 10% (Refer Fig. 5.9). This methodology helps to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours (Refer Fig. 5.10) was also minimized as a result in turn decrease of throughput time. On the basis of proper study and analysis of the OEE before and after implementation, it has been shown that a remarkable growth, which is an indication of an increase in equipment availability, performance, and quality.

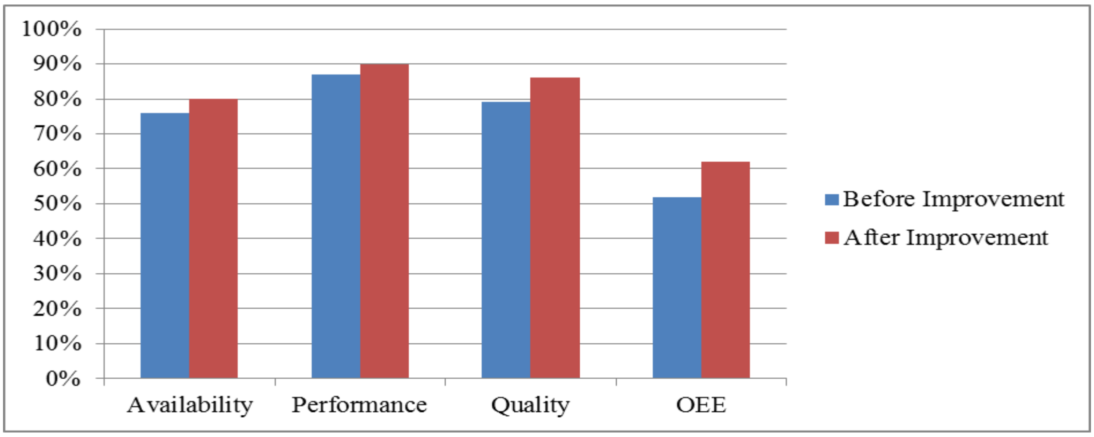

Fig 5.9: Comparison of OEE its factor Before & After Improvement.

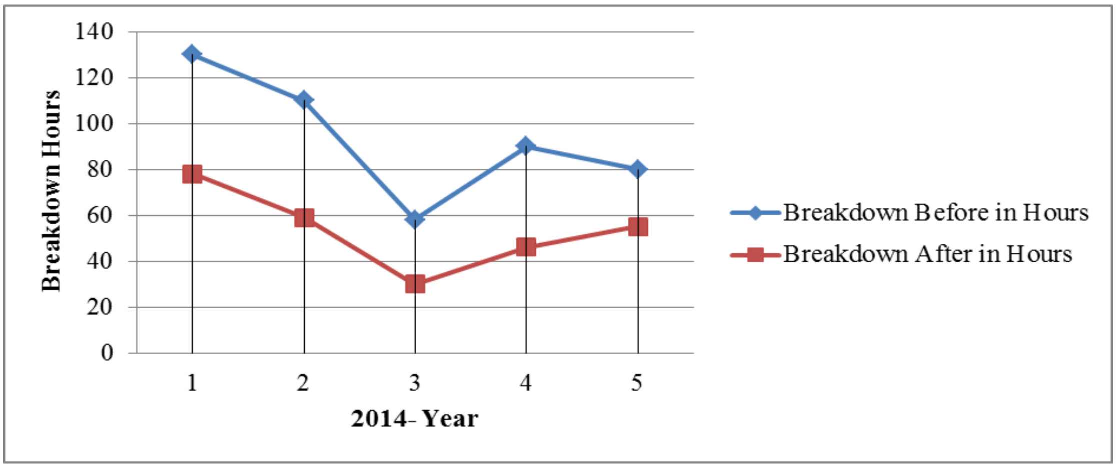

Fig 5.10: Comparison of Breakdown Hours Before & After Improvement.

5.7 Methodology for determining the status of Reclaimer: Parameters, aspects, and technology.

Table 5.6: Methodology for determining the status of Reclaimer.

Parameter	Component	Sensor/Technology
Vibration	Motor Gear Box	Acoustic vibration sensor Accelerometer Vibration analyzer Instrument
Power	Motor	Watt meter Torque Sensor
Speed	Motor Main travel gearbox	Optical/ Magnetic encoder Magnetic RPM picks up sensor
Temperature	Material Gear Box Motor Hydraulic oil	Thermocouple Infrared temperature sensor
Torque	Motor shaft Brake shaft	Torque meter
Force & Tension	Chain the main beam	Strain gauge
Pressure	Hydraulic oil Lubrication oil	Pressure gauge
Shock	Gear Box Coupling (Revolving element like ball & roller bearing)	Shock pulse meter
Minor Crack	All accessories in Reclaimer	Ultrasonic flaw detector
Hotspot	Bearing Other parts of machinery	Infra-red thermometer Remote sensing
Thickness of paint, coating	Structure and its component	Ultrasonic/ Eddy Current thickness meter
Corrosion	Reclaimer equipment like, chain main beam, structure etc...	Corrosion meter
Leakage	Oil at high pressure	Ultrasonic Leak Detector

5.7.1 Result & Discussion of Reclaimer

After implementing this methodology in coal handling plant of reclaimer section, it is found that the overall equipment effectiveness is maximized by 8% (Refer Fig. 5.11). This methodology helps to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours (Refer Fig. 5.12) was also minimized as a result, in turn, decrease of throughput time. On the basis of proper study and analysis of the OEE before and after implementation, it has been shown that a remarkable growth, which is an indication of an increase in equipment availability, performance, and quality.

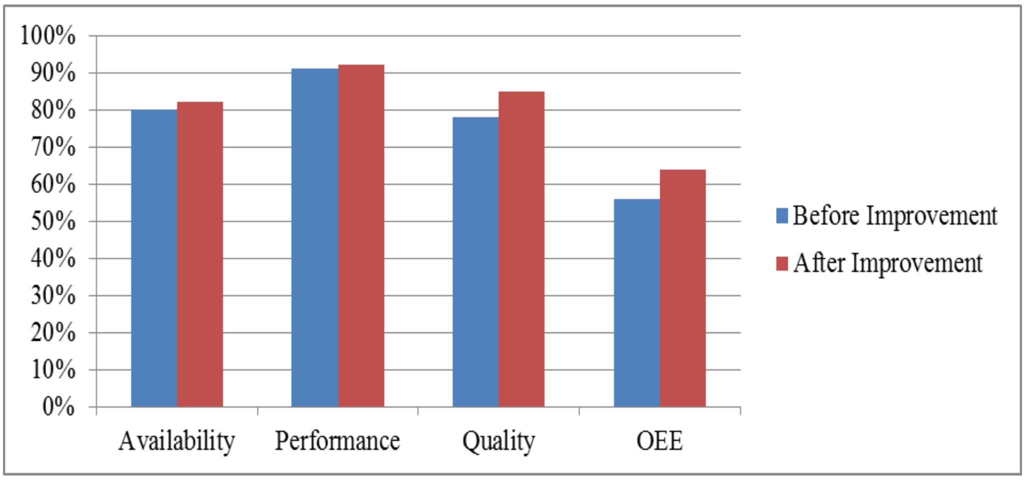

Fig 5.11: Comparison of OEE its factor Before & After Improvement.

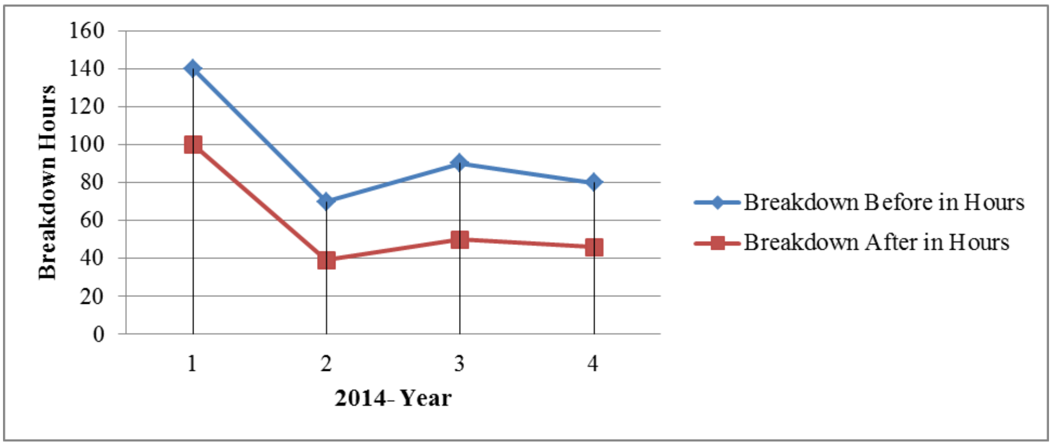

Fig 5.12: Comparison of Breakdown Hours Before & After Improvement.

5.8 Summary

This chapter equally divides into two parts. The first part presents the suggestion of appropriate methodology through tables for determining the status of coal handling equipment viz. Tippler, Side arm charger, Reversible apron feeder, Belt conveyor system, Stacker, Reclaimer. The second part emphasizes the result and discussion of above coal handling equipment through figures and it is found that the overall equipment effectiveness is maximized after implementation of this methodology which is helped to increase their availability, quality and performance of coal handling plant by controlling the losses that affected the production and the number of breakdown hours are also minimised.

Chapter 6

CASE STUDY APPLICATION

6.1 Overview

In the coal handling industries, it is observed that sudden breakdown of any equipment may stop the entire system, resulting in drastic production loss and enhancing the cost of production. In this chapter, the probabilities of a sudden breakdown of each equipment are individually analyzed from their previous performance where the frequency of occurrences, duration, and time interval of each breakdown has given additional stress and non-availability of that equipment. Computerized best fit matching is found out for preventive maintenance of these equipment by developing different sub-routines and simulation models.

6.2 Simulation Models

To minimize breakdown period it was badly needed to analyze them statistically by the simulation model, viz.

(i) Generation of uniformly distributed random numbers,

(ii) Generation of normally distributed random numbers,

(iii) System simulation on event to event types analysis,

(iv) Identification of event by statistical distribution,

(v) Preparing sub-routine skewing of uniformly distributed random numbers to a histogram.

6.3 Uniformly Distributed Random Numbers

It was generated by multiplicative congruential generator or power residue generator (Fig………) which consisted of

$X_{i+1} = X_i * a$ (modulus M)

In the present work was done by

$X_{i+1} = 24298\ X_i\ + 9991 \bmod 199017$

$R_{i+1} = X_{i+1} /m = X_{i+1} / 199017$

$X_0 = 199017 * R_0$

6.4 Normally Distributed Random Number

These are the numbers where the probability of all the number not same. As such there was no specific table to those numbers and were generally made by converting the uniformly distributed random numbers with the help of a computer. There is a lot of procedure for this conversation. Mostly computation was done like this:

Let, the independently and identically distributed random variables are X_1, X_2, X_3……. X_d for U (0, 1) and mean of those numbers is $\overline{X}$.

So for U (0, 1), Expectation (E) = $\frac{1}{2}$ and

Variance (V) = 1/12d and by Central Limit Theorem

$X \sim N (E(\overline{x}), v(\overline{x})) = N (1/2, 1/\sqrt{12d})$

Or $(\overline{x}\text{-}1/2) \sqrt{12d} \sim N (0,1)$

Thus, n observed from uniform gives 1, obs. From normal. The conversion procedure which was used for solving these work are:

If R_4 was a normally distributed random number (RN) with mean (μ) = 0 and standard deviation (σ) = 1 then the conversation was done [Fig. 6.1] by $RN = R_4.\sigma + \mu$

where $R_4 = [-2.\text{In}.R_2]^{1/2} * \cos [2\pi R_3]$

6.5 System Simulation on Event to- Event Analysis

Different subroutines for different events were prepared in this simulation model and the sub-routines were design based on the frequency distribution of different breakdown which occurred in the coal handling system. The duration of each breakdown was analyzed. From the cumulative frequency distribution, the random numbers were generated from random number distribution table. These randomizing cases were stochastically distributed because the breakdown of different equipment could not follow a particular path. So, by generating the uniformly distributed random numbers and then converting them to a normally distributed one, it was possible to identify which event could come first and so on. Though cases may arose also a particular event occurred twice at a time. As a result, event analyzes were needed for this present simulation [Table 6.1-6.20].

6.6 Event Identification

This means to determine event which would come first, second and so on. In the present work 6 events were considered demarcating by 1, 2, 3…. 6 when the breakdown of any equipment took place in the coal handling system and rectifying this breakdown another one went out-of-order. By statistical distribution, it was identified the sequential occurrence of different events, i.e which event will occur first and so on. A clock schedule of the activity was maintained and a stimulatory list was prepared from the distribution function. If more than one event was scheduled to be executed, the tie-breaking rules specified by the SELECT function was determined to identify the event actually executed. For the identification of this events, a special; event sub-routines was prepared which followed the different event sub-routine and the frequency distribution helps to prepare this identification.

6.7 Sub Routine Skewing of Uniformly Distributed Random Number

Coal handling equipment data were analyzed and from the data histogram were prepared [Table 6.1- 6.20]. It was seen that for 6 different events breakdown in the plant production was hampered. These breakdown events were not uniformly distributed, their frequency distributions were also different. Once the first event was broken down, did not mean that in the ninth term it could be broken down. These irregularities were following the normal distribution curves and their histograms were not showing smooth curves. The mean of the frequency curves was right to the mode and just reverse was also not impossible. These 6 events subroutine skewing of was replaced to the uniformly distributed random numbers to the histogram, the solution of the problem was much easier than the problems which were dealt in this thesis.

6.8 Performance Appraisal of Coal Handling Machineries

The 6 events which were identified from the coal handling data analyzed were:

Event 1: Breakdown of Tippler

Event 2: Breakdown of Side Arm Charger

Event 3: Breakdown of Reversible Apron Feeder

Event 4: Breakdown of Belt Conveyor System

Event 5: Breakdown of Stacker

Event 6: Breakdown of Reclaimer

The breakdown data of all the 6 events were analyzed for a period of one year.

6.9 Specific Example for Data Analysis

The list of following tables shows the break-down data analysis of different types of machinery.

Table 6.1 : Frequency and period of existancy of the breakdown of tippler equipment for the year of 1st April 2013 to 31st March 2014.

Sl no.	**Types of breakdown**	**Period of b/d**	**Duration(hrs)**	**Frequency**	**Total b/d (hrs)**
1	Empty side winch rope snapped	10.4.13 (9am-16.15pm) 16.12.13 (9.30am-13pm)	7.15 & 3.30	2	10.45
2	Upper clamp hood beam came out	3.4.13 (1.00am-16.30pm)	15.3	1	15.3
3	Cylinder oil leakage	21.5.13 (5.00am-10.45am) 1.5.13 (9am-16pm)	5.45 & 7.00	2	12.45
4	Rake mounting circle was broken	1.5.13 (4.15am-18pm)	61.75	1	61.75
5	Upper clamp channel broken	9.6.13 (1.00am-21.30pm)	20.3	1	20.3
6	Empty side track damaged	8.10.13 (16.00pm-6.00am)	14	1	14
7	Upper clam hood welding detached	3.10.13 (10.45am-16pm)	5.15	1	5.15
8	Side clamp arm broken	9.12.13 (7.05am-12.45pm)	5.4	1	5.4

Table 6.2: Conversion of the interval between tippler break-downs to cumulative random numbers.

Interval between Tippler breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-10	2	2000	0 – 2000
10-20	1	1000	2001-3000
20-30	2	2000	3001-5000
30-40	1	1000	5001-6000
40-50	1	1000	6001-7000
50-60	1	1000	7001-8000
60-70	1	1000	8001-9000
70-80	1	1000	9001-10000
	10	10,000	

Table 6.3: Conversion of existancy of tippler break-downs to cumulative random numbers.

Existence of Tippler Breakdown	Frequency of occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-1	2	2000	0-2000
1-2	1	2000	2001-3000
2-3	2	2000	3001-5000
3-4	1	1000	5001-6000
4-5	1	1000	6001-7000
5-6	1	1000	7001-8000
6-7	1	1000	8001-9000
7-8	1	1000	9001-10000
	10	10,000	

Table6.4: Frequency and period of existancy of the breakdown of side arm charger equipment for the year of 1st April 2013 to 31st March 2014.

Sl no.	**Types of breakdown**	**Period of breakdown**	**Duration (hrs)**	**Frequency**	**Total b/d (hrs)**
1	Side arm coupler broken	8.4.13 (1.30am-21pm)	19.3	1	19.3
2	Hydraulic oil leakage	25.5.13(9-21.45)	3.45	1	3.45
3	Pinion position shifted	27.6.13 (5.10-9am)/ 15.6.13 (8am-12.23pm)	3.50 & 4.23	2	8.13
4	Coupler cylinder piston broken	1.5.13 (4.15am-18pm)	4	1	4
5	Coupler limit switch rod broken	8.11.13 (17.20pm-19.45pm)	2.25	1	2.25
6	Rack bolt loss & broken	3.12-4.12.13 (22pm-1.55am)	3.55	1	3.55
7	Sac guide wheel fallen	26.10.13 (6.36am-16pm)	9.24	1	9.24

Table 6.5: Conversion of the interval between side arm charger break-downs to cumulative random numbers.

Interval between SAC Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-10	1	1000	0 – 1000
10-20	1	1000	1001-2000
20-30	2	2000	2001-4000
30-40	1	1000	4001-5000
40-50	1	1000	5001-6000
50-60	1	1000	6001-7000
60-70	1	1000	7001-8000
	8	8000	

Table 6.6: Conversion of existancy of side arm charger break-downs to cumulative random numbers.

Existence of SAC Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-1	1	1000	0-1000
1-2	1	2000	1001-2000
2-3	2	2000	2001-4000
3-4	1	1000	4001-5000
4-5	1	1000	5001-6000
5-6	1	1000	6001-7000
6-7	1	1000	7001-8000
	8	8000	

Table 6.7 :Frequency and period of existancy of the breakdown of reversible apron feeder equipment for the year of 1st April 2013 to 31st March 2014.

Sl. No.	**Types of breakdown**	**Period of breakdown**	**Duration(hrs)**	**Frequency**	**Total b/d hrs**
1	Wearing plate damaged	13.8.13 (11.30am-16.10pm) 18.9.13 (1pm-5pm)	4.40 & 4.00	2	8.40
2	G/B damaged	21.12.13(7am-15pm)	5.20	1	5.20
3	Apron plate damaged	16.2.14(16pm-23pm)	4	1	4

Table 6.8: Conversion of the interval between reversible apron feeder break-downs to cumulative random numbers.

Interval between RAF Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-10	2	2000	0 – 2000
10-20	1	1000	2001-3000
20-30	1	1000	3001-4000
	4	4000	

Table 6.9: Conversion of existancy of reversible apron feeder break-downs to cumulative random numbers.

Existence of RAF Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-1	2	2000	0-2000
1-2	1	1000	2001-3000
2-3	1	1000	3001-4000
	4	4000	

Table 6.10 : Frequency and period of existancy of the breakdown of belt conveyor equipment for the year of 1st April 2013 to 31st March 2014.

Sl no.	**Types of breakdown**	**Period of breakdown**	**Duration (hrs)**	**Frequency**	**Total b/d(hrs)**
1	Take up pulley bearing housing damaged	27.4.13(15.30pm-21pm)	5.3	1	5.3
2	Turbo coupling damaged	14.7.13 (11.50am-18.30pm)/ 17.1.14 (5.15am-10.45am)	6.40 & 5.30	2	12.1
3	T/end drum bearing damaged	1.8.13 (10.30am-15.15pm)/ 14.9.13(14pm-18pm)	4.45 & 4.00	2	8.45
4	T/end drum out from housing	4.11-5.11.13 (19.30pm-18.30pm)	23	1	23
5	Belt through cut	17.12.13 (2.30am-12.15pm)	9.45	1	9.45
6	Belt snapped	16.7.13(10am-17pm)	7	1	7
7	Belt structure broken	4.1.14(10am-21.15pm)	11.15	1	11.15
8	Bearing damaged	12.1.14(15.30pm-19pm)	3.3	1	3.3

Table 6.11: Conversion of the interval between belt conveyor system break-downs to cumulative random numbers.

Interval between BCS breakdown	Frequency of occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-10	1	1000	0 – 1000
10-20	2	2000	1001-3000
20-30	2	2000	3001-5000
30-40	1	1000	5001-6000
40-50	1	1000	6001-7000
50-60	1	1000	7001-8000
60-70	1	1000	8001-9000
70-80	1	1000	9001-10000
	10	10,000	

Table 6.12: Conversion of existancy of belt conveyor system break-downs to cumulative random numbers.

Existence of BCS Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-1	1	1000	0-2000
1-2	2	2000	1001-3000
2-3	2	2000	3001-5000
3-4	1	1000	5001-6000
4-5	1	1000	6001-7000
5-6	1	1000	7001-8000
6-7	1	1000	8001-9000
7-8	11	1000	9001-10000
	10	10,000	

Table 6.13 : Frequency and period of existancy of the breakdown of stacker equipment for the year of 1st April 2013 to 31st March 2014.

Sl. No	**Types of breakdown**	**Period of b/d**	**Duration(hrs)**	**Frequency**	**Total b/d(hrs)**
1	Slew gear box damaged	22.5.13(9am-18pm)	9	1	9
2	Slew gear pinion damaged	27.7.13(10.30am-12.30pm)	2	1	2
3	Failure of boom luffing system	5.9.13-6.9.13(3am-4am)	25	1	25
4	Main travel g/b damaged	11.11.13(15pm-11am)	20	1	20
5	Boom conveyor snapping	2.2.14(10am-22pm)	12	1	12

Table 6.14: Conversion of the interval between stacker break-downs to cumulative random numbers.

Interval between stacker breakdown	Frequency of occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-10	1	1000	0 – 1000
10-20	1	1000	1001-2000
20-30	1	1000	2001-3000
40-50	1	1000	3001-4000
50-60	1	1000	4000-5000
	5	5000	

Table 6.15: Conversion of existancy of stacker break-downs to cumulative random numbers.

Existence of stacker Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Nos
0-1	1	1000	0-1000
2-3	1	1000	1001-2000
3-4	1	1000	2001-3000
4-5	1	1000	3001-4000
5-6	1	1000	4001-5000
	5	5000	

Table 6.16 : Frequency and period of existancy of the breakdown of reclaimer equipment for the year of 1st April 2013 to 31st March 2014.

Sl. No	**Types of breakdown**	**Period of b/d**	**Duration(hrs)**	**Frequency**	**Total b/d(hrs)**
1	Chaine main beam got damaged	8.11.13(11.15am-20.15pm)	9	1	9
2	Derailment	2.12.13-3.12.13(10am-13pm)	26	1	26
3	Snapping of chaine	12.1.14(9am-17pm)	8	1	8
4	G/b damaged	17.2.14(10.30am-15.30pm)	5	1	5
5	Driving system failed	28.3.14(13.10-17.10)	4	1	4

Table 6.17: Conversion of the interval between reclaimer break-downs to cumulative random numbers.

Interval between reclaimer breakdown	Frequency of occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Numbers
0-10	1	1000	0 – 1000
10-20	1	1000	1001-2000
20-30	1	1000	2001-3000
40-50	1	1000	3001-4000
50-60	1	1000	4000-5000
	5	5000	

Table 6.18: Conversion of existancy of reclaimer break-downs to cumulative random numbers.

Existence of reclaimer Breakdown	Frequency of Occurrence	Frequency of occurrence % * Random Nos	Cumulative Random Nos
0-1	1	1000	0-1000
2-3	1	1000	1001-2000
3-4	1	1000	2001-3000
4-5	1	1000	3001-4000
5-6	1	1000	4001-5000
	5	5000	

Table 6.19: Different events of break-downs, their frequencies, and random-number distribution.

Sl No	Different Events of Breakdown	Total frequency of Breakdown	Frequency of Breakdown in	Random Number Distribution
1	Breakdown of Tippler	10	0.2381	2381
2	Breakdown of SAC	8	0.1904	1904
3	Breakdown of RAF	4	0.0952	952
4	Breakdown of Belt conveyor	10	0.2381	2381
5	Breakdown of Stacker	5	0.1191	1191
6	Breakdown of Reclaimer	5	0.1191	1191
		42	1	10000

From the above-mentioned analysis it is observed that the random number distribution can give some indication about the occurrences of the break-down of different events like;

Table 6.20: Indicating occurrences of break-down using random number distribution.

Sl No	Events	Distribution of random number
1	Breakdown of Tippler	1-2381
2	Breakdown of SAC	2382-4285
3	Breakdown of RAF	4286-5237
4	Breakdown of Belt conveyor	5238-7618
5	Breakdown of Stacker	7619-8890
6	Breakdown of Reclaimer	8890-10000

FLOW CHART SHOWING SUB-ROUTINE (I) UNRAND, (II) NORAND

(I) UNRAND (II) NORAND

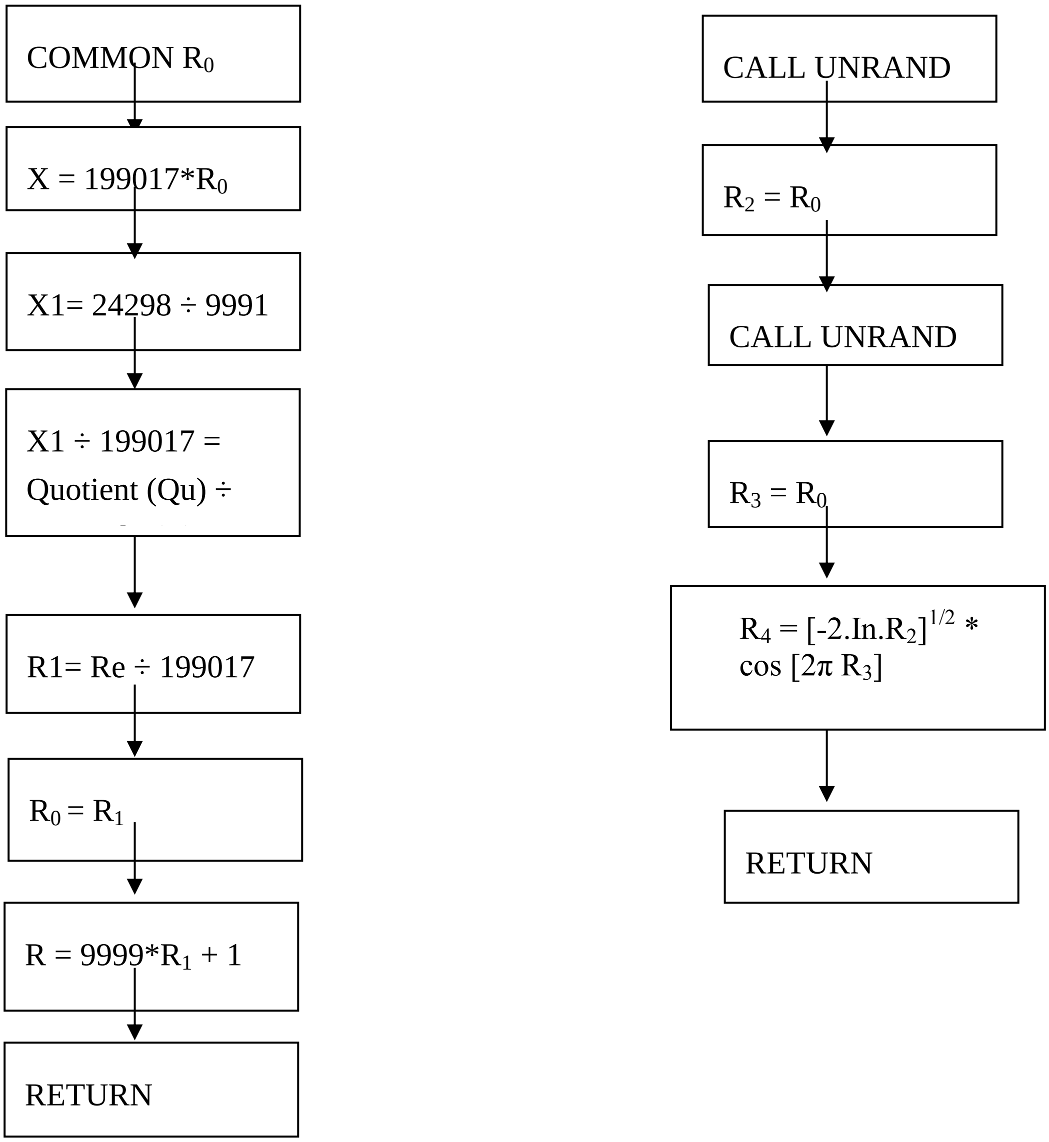

Fig. 6.1: Flow chart showing sub-routine UNRAND & NORAND.

FLOW CHART SHOWING SUB-ROUTINE EVENT

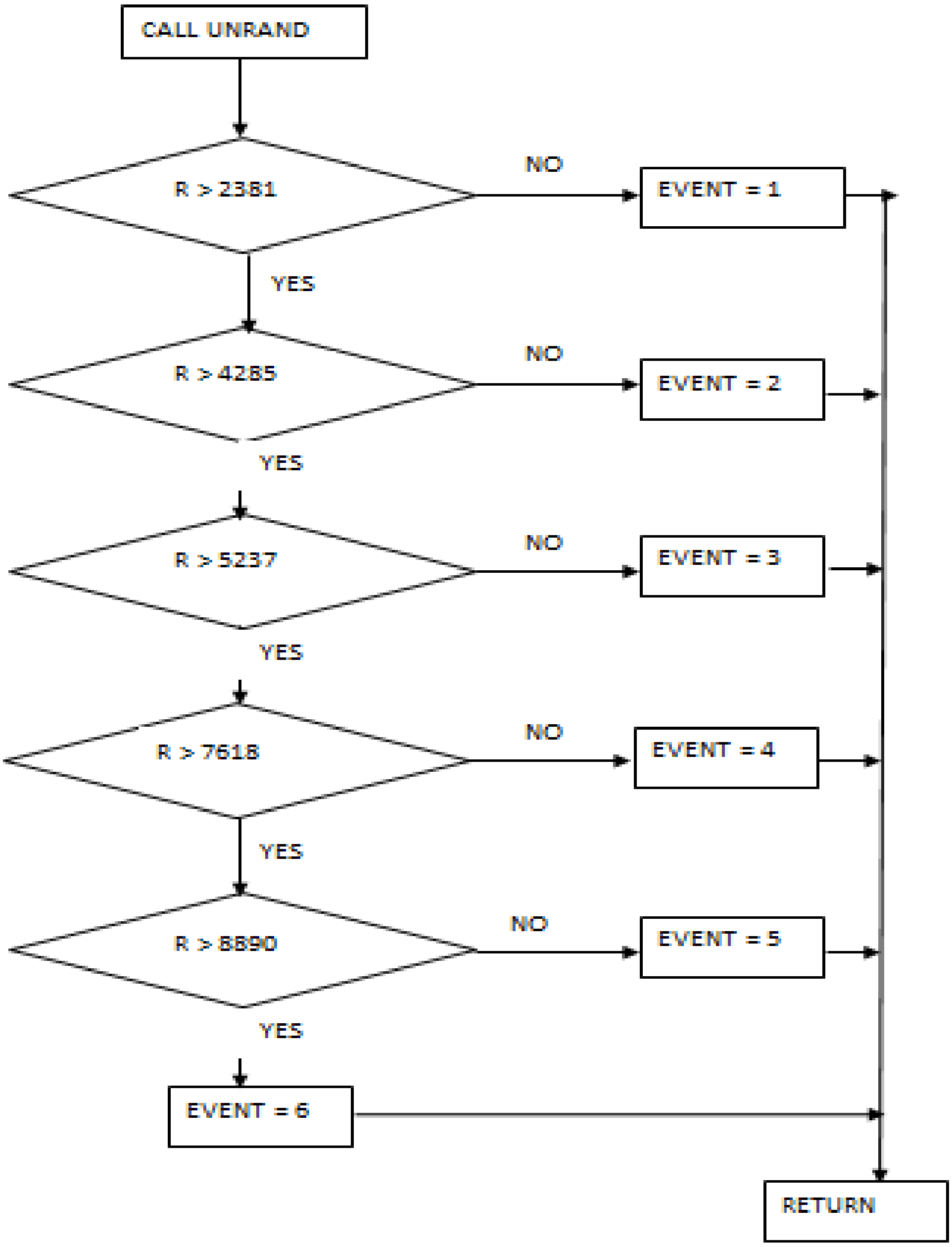

Fig. 6.2: Flow chart showing sub-routine event.

FLOW CHART SHOW SUB-ROUTINE TIPPLER BREAKDOWN

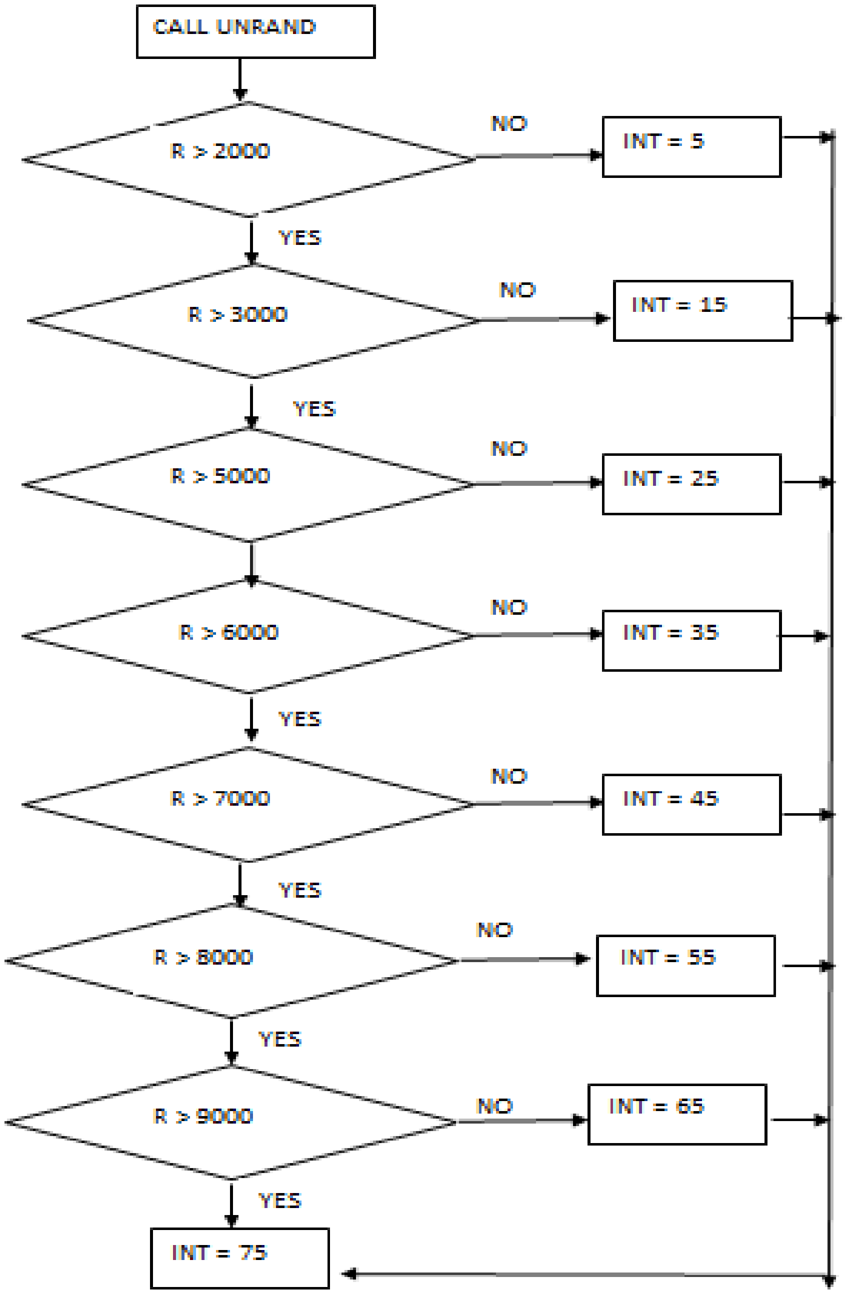

Fig. 6.3: Flow chart show sub-routine tippler breakdown.

FLOW CHART SHOW SUB-ROUTINE SIDE ARM CHARGER BREAKDOWN

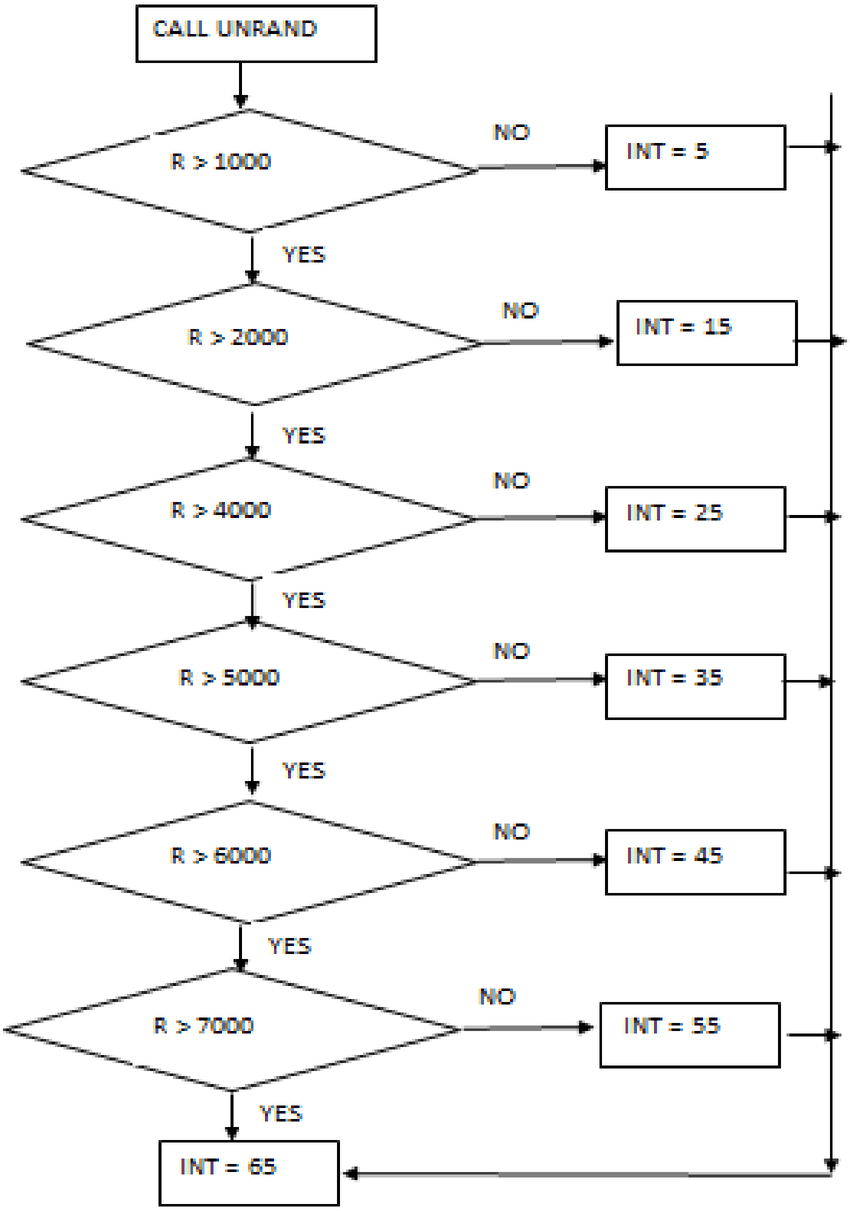

Fig. 6.4: Flow chart show sub-routine side arm charger breakdown.

FLOW CHART SHOW SUB-ROUTINE REVERSIBLE APRON FEEDER BREAKDOWN

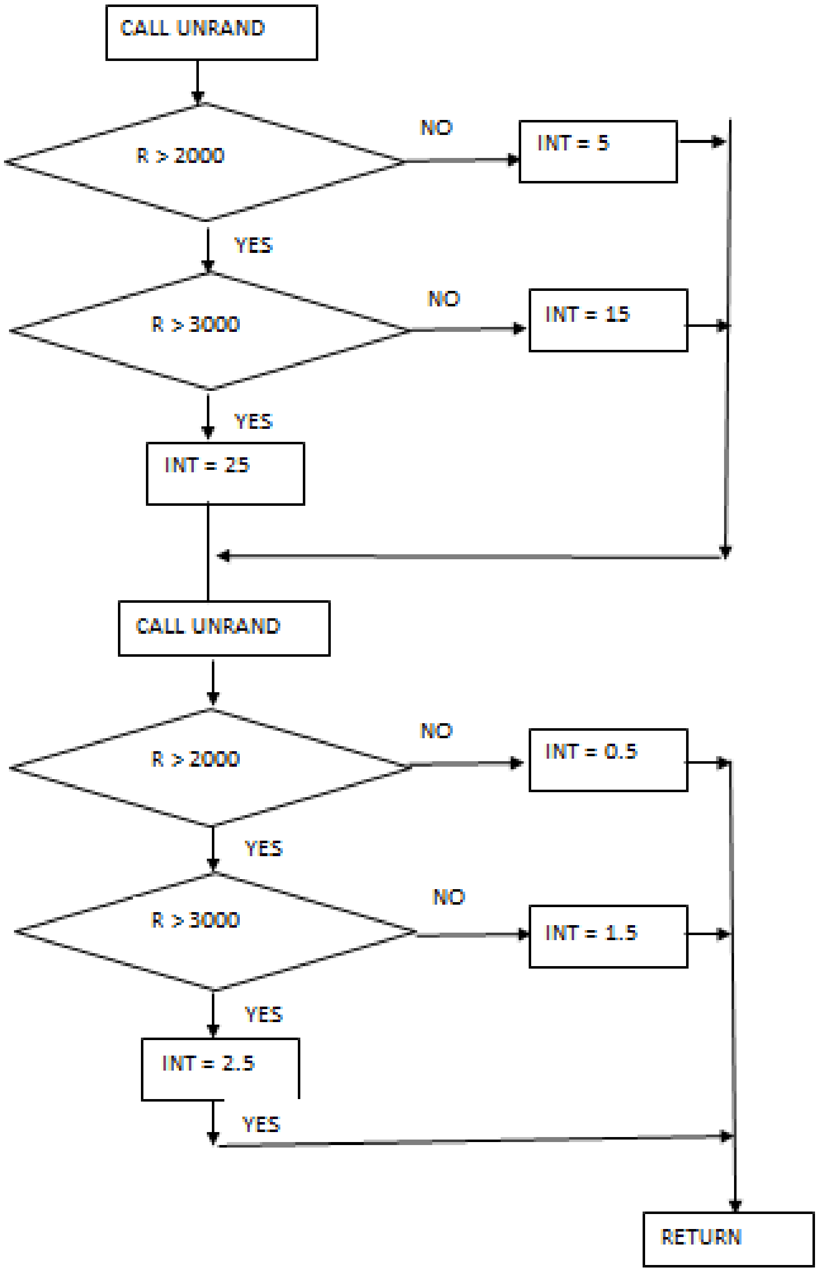

Fig. 6.5: Flow chart show sub-routine reversible apron feeder breakdown.

FLOW CHART SHOW SUB-ROUTINE BELT CONVEYOR BREAKDOWN

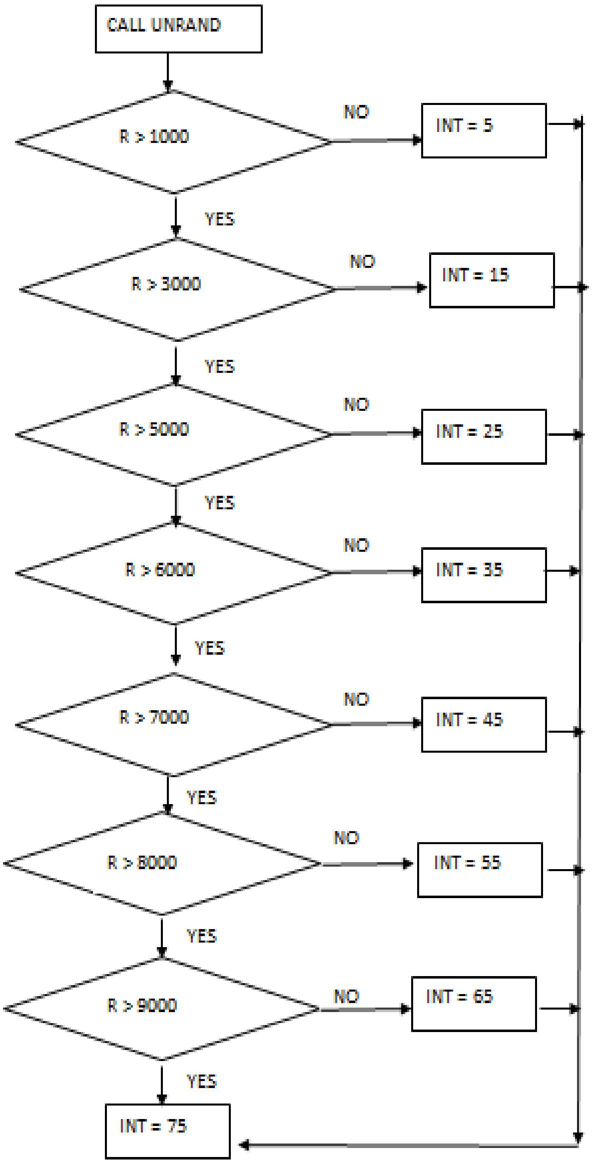

Fig. 6.6: Flow chart show sub-routine belt conveyor breakdown.

FLOW CHART SHOW SUB-ROUTINE STACKER BREAKDOWN

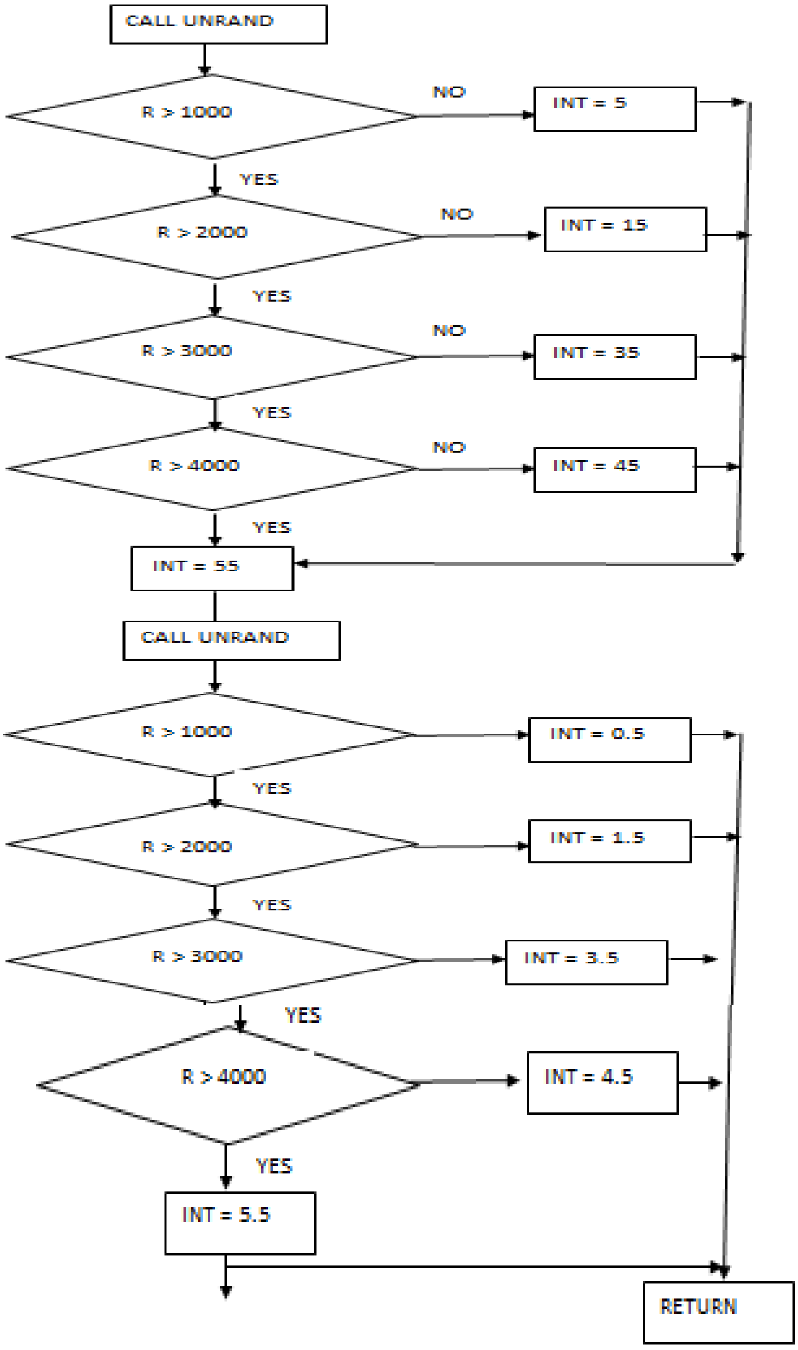

Fig. 6.7: Flow chart show sub-routine satcker breakdown.

FLOW CHART SHOW SUB-ROUTINE RECLAIMER BREAKDOWN

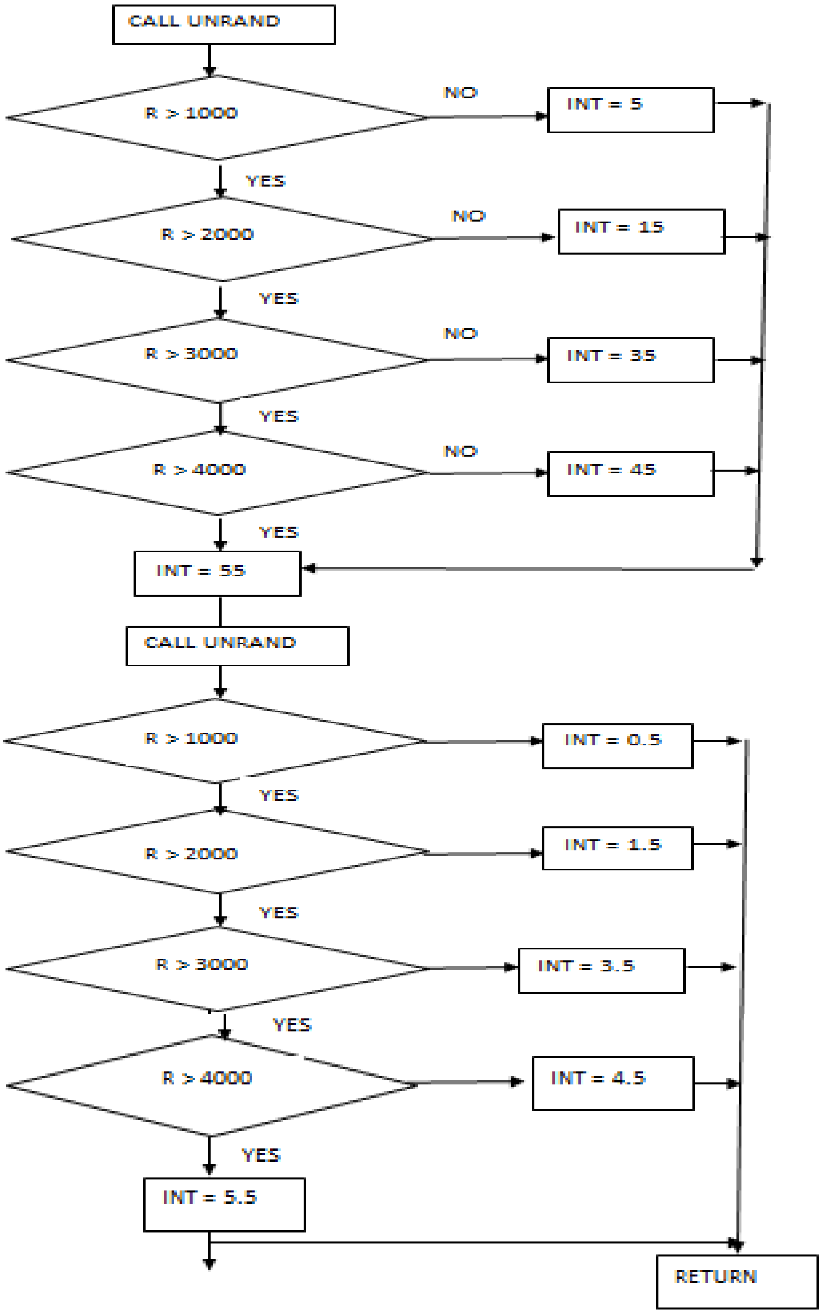

Fig. 6.8: Flow chart show sub-routine reclaimer breakdown.

6.10 Summary

In this study, modeling and simulation algorithm is used based on breakdown data of the different types of machinery generating uniformly distributed random numbers. The breakdown of different types of machinery was analyzed with random number distribution. The different equipment fall under definite random number distribution range. Such as if the random number comes as 1 - 2381 indicates the tippler breakdown and if it comes 2382- 4285 it is considered as side arm charger break-down, etc.

Chapter 7

CONCLUSION AND FUTURE SCOPE

7.1 Overview

The performance of equipment can be improved and controlled, successfully. An appropriate methodology for preventive measurement system can be used. OEE is a known method to measure the performance of production equipment in coal handling plant which aims to identify the unproductive loss within the system & these time losses affect availability, performance, and quality.

7.2 Conclusion

This research work concludes in 2 broad areas.

Firstly, OEE is an indicator of process improvement. The role and contribution of OEE within the context of performance measurement with a specific observation regarding the implementation OEE within the case are presented which shows that the six big time losses for coal handling machinery can be minimized.

Secondly, different types of sensors are used for knowing the status of the parameters of the equipment which also maximizes their production rate to help the management for smooth operation.

So, it is concluded that if OEE is implemented in coal handling plant equipment, the company can improve their availability, performance rate, and quality rate. As a result, the overall equipment effectiveness can be improved. Thereby the company can enhance the annual earning and profit. To achieve or may reach the target (world class OEE) efficient measurement is necessary in order to establish the autonomous maintenance teams, better communication, and teamwork. It is essential that the company devices an efficient data recording systems so that at any time up to date and accurate information will be available to the management. It also gives an opportunity to the operators to raise their skills and know-how to foster improvement suggestions.

7.3 Contribution

Based on the field studies and analysis of data of availability, performance and quality of coal handling machinery following conclusions are arrived at:

- The OEE of the tippler equipment is increased from 56% to 64% and breakdown hour reduces from 635 to 268.
- The OEE of the side arm charger equipment is increased from 64% to 68% and breakdown hour reduces from 490 to 250.
- The OEE of the reversible apron feeder equipment is increased from 61% to 68% and breakdown hour reduces from 229 to 125.
- The OEE of the belt conveyor equipment is increased from 51% to 61% and breakdown hour reduces from 820 to 424.
- The OEE of the stacker equipment is increased from 52% to 62% and breakdown hour reduces from 468 to 268.
- The OEE of the reclaimer equipment is increased from 56% to 64% and breakdown hour reduces from 380 to 235.

The above results show much more improvement of the coal handling equipment and reach the world class OEE by continuing with measurement and team effort. Hence, it increased in availability, better utilization of resources, reduction in the defect, wastage, minor stoppage, downtime, labour cost and promote safety and increase morale and confidence of employee and thereby achieving goals by working as a team.

7.4 Future scope of work

The research work can be put forward towards the following area of research:

- Overall Equipment Effectiveness(OEE) is the one of the best tools not only applied for coal handling plant but also applicable in all the industries such as mining, manufacturing, automobile, cement, power, steel, construction, petroleum, food, marine, aeronautical etc.
- Further research can be conducted to evaluate the efficiency losses in terms of cost.
- Overall line efficiency can be determined as a function of the on-line equipment's OEE metrics.
- With the application of OEE, inadequate parameters, which are barriers to performance can be identified, modified and implemented.
- A variety of sensors can be used with the help of different sensors technology for fault finding automatically in terms of alarms, indications and hence reducing human errors.

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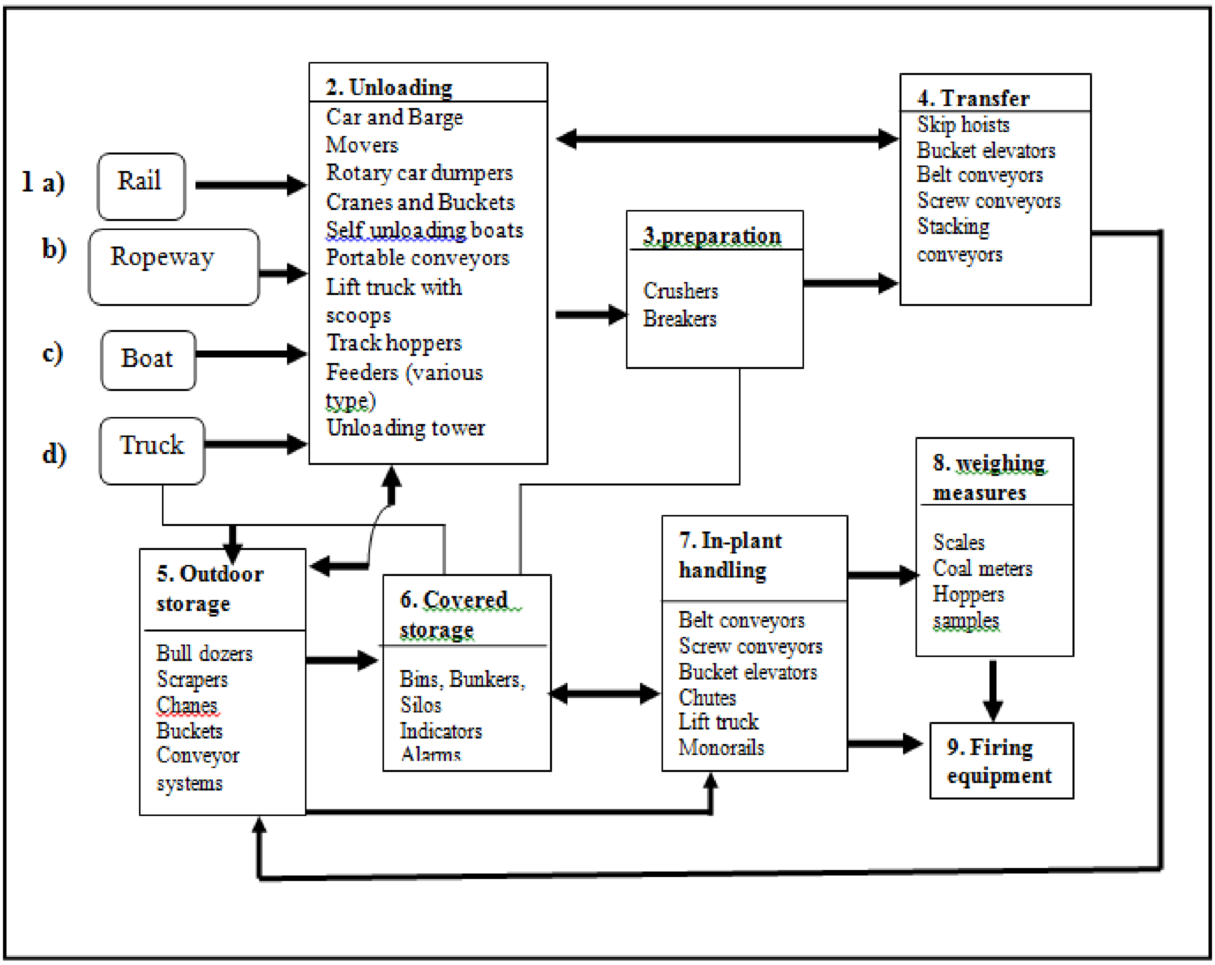
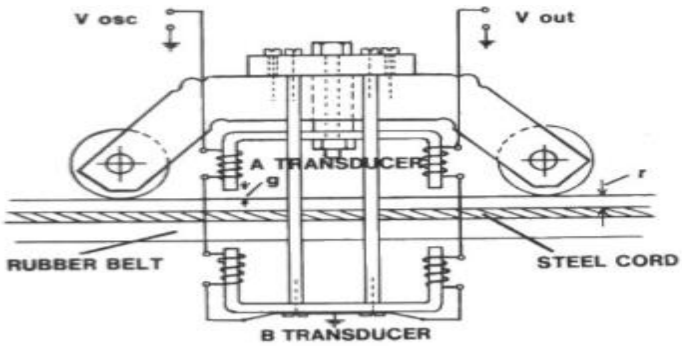
Appendix

FLOW OF COAL THROUGH PLANT

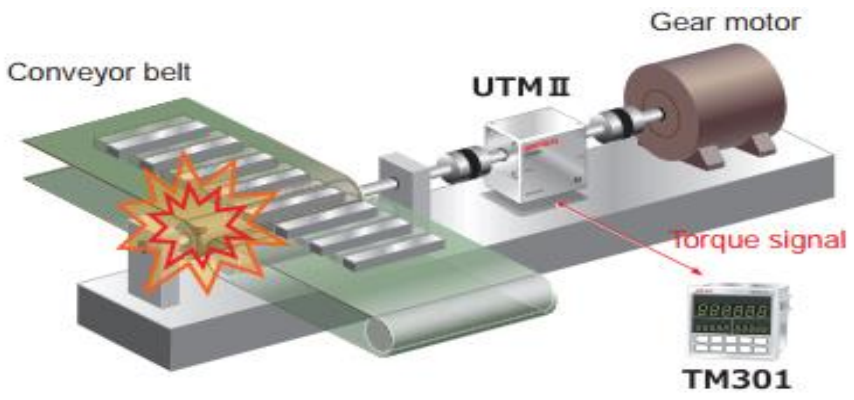


Visual detection by man on the surface of the conveyor belt.

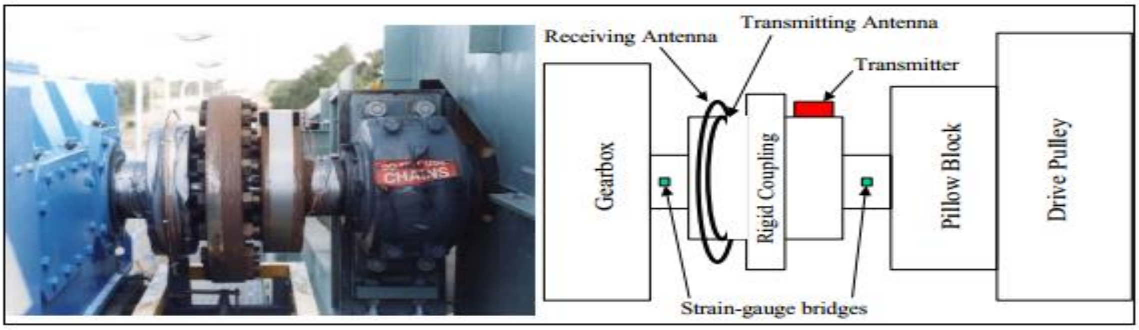


Steel cord monitoring of conveyor belt by conductive detection.

Belt speed monitoring by tachometer installing on carrying side of belt

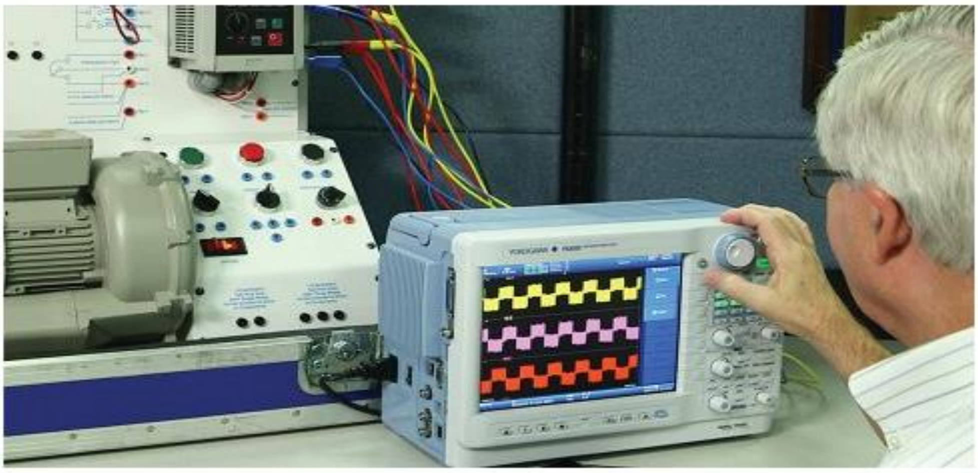


Torque monitoring of shaft installed in belt conveyor system by sensor



A typical strain-gauge measurement set up in conveyor belt system

Vibration monitoring by Vibration analyser instrument



Power monitoring of motor

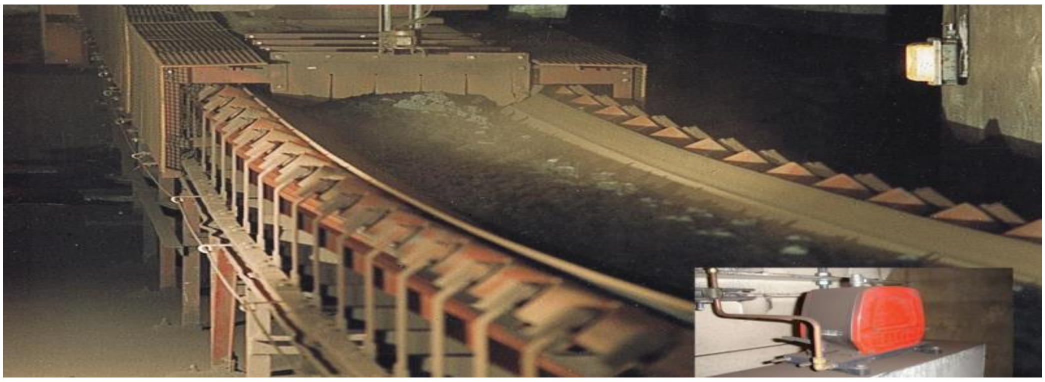
Belt alignment control monitoring the belt misalignment

Two encoder mounted on pulley to measure the position

Temperature monitoring of temperature analyser instrument

Shock monitoring by shock pulse meter

Minor crack monitoring by ultrasonic flow detector



Safety instrument for spot monitoring hot material

conveyor belt rupture detector

Thickness testing of conveyor belt

Hot spot detecting by infra-red thermometer

Ultrasonic thickness meter monitoring the thickness of paint and coating

Corrosion monitoring by corrosion meter

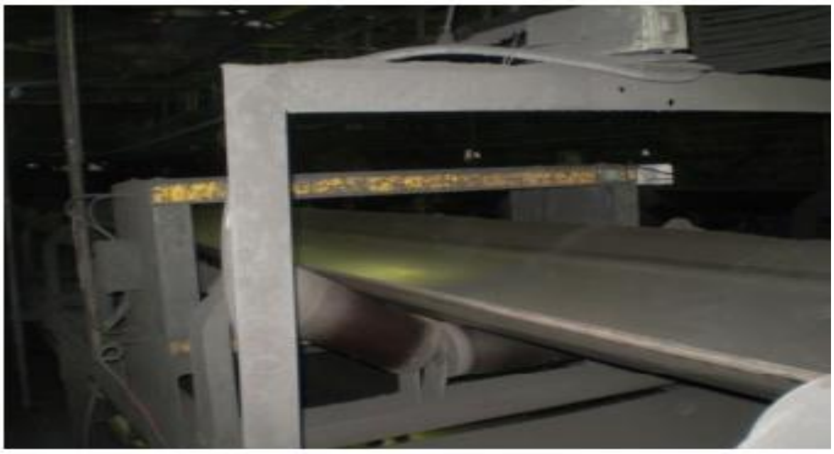
Laser Alignment is a highly accurate system to align framework and conveyor components

Idler tracking system in BCS

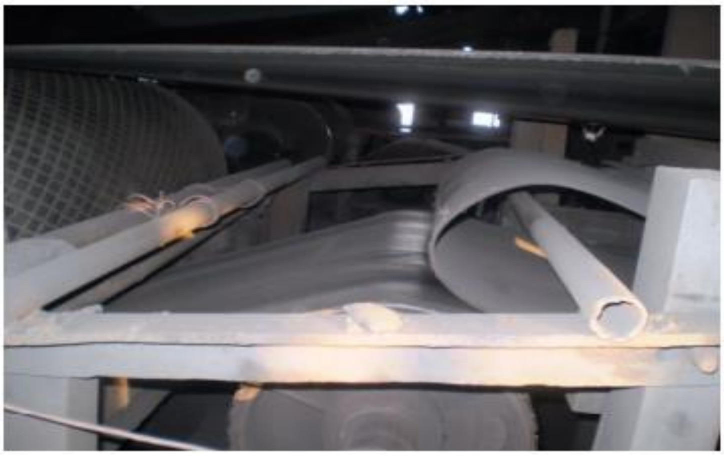
Belt misalignment switch

Grilling system for protection of spillage of coal

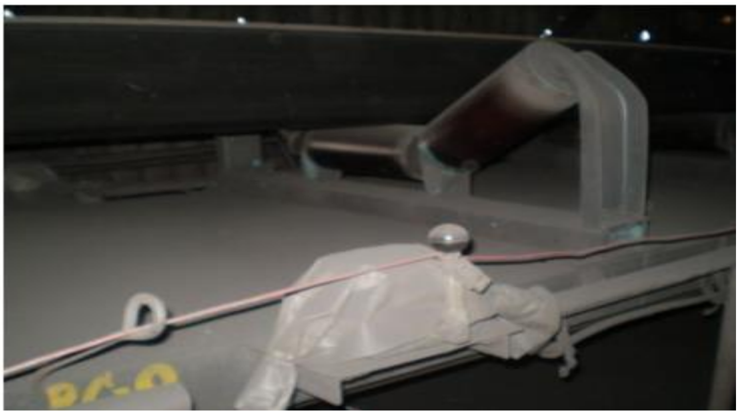
Online coal quality measurement by electric sensor



Metal detector for online monitoring of mild steel

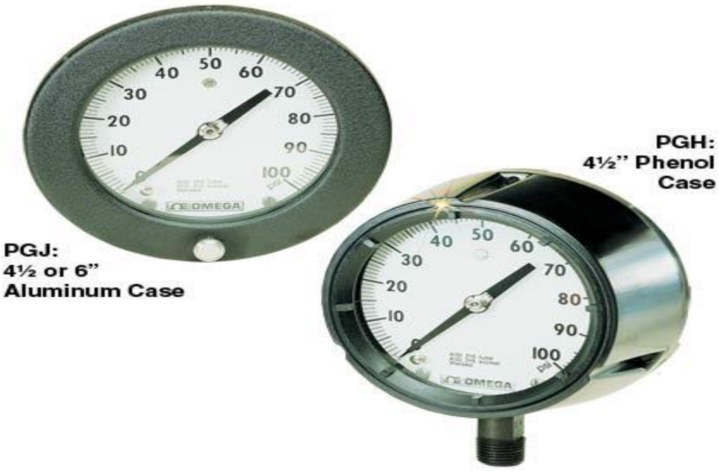


Hold back is a breaking system for protecting the belt during power failure

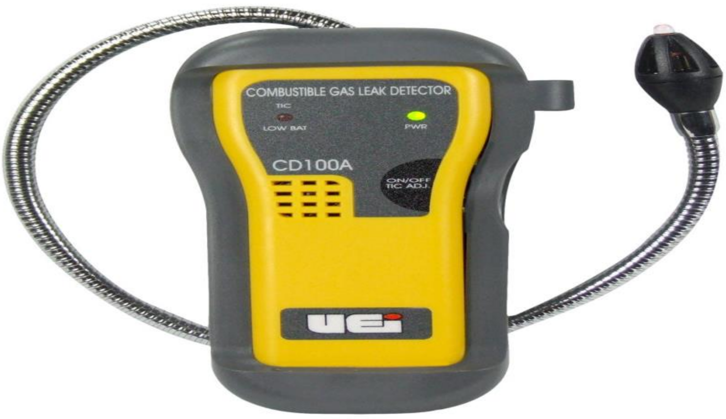


Pull cord switch is a protecting device operated manually by operator

Belt sway switch is a protecting device for excessive running out and getting edge damaged



Hydraulic pressure gauge monitoring



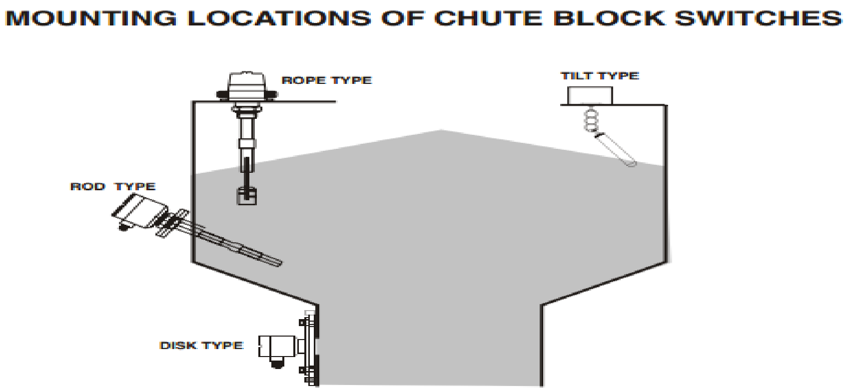
Hydraulic oil leakage monitoring by ultrasonic leak detector

Wheel speed monitoring by sensor

Laser distance meter to measure the length

Controlling the long travel speed of stacker/reclaimer by VFD Panel

OneproD MVX Multi channel online monitoring system is used for remote monitoring of distance machines (oil platforms, remote plants, etc.)



Introducing the sensors for chute jamming

Introducing gladiator microwave switch, for protecting the boom of stacker/reclaimer on contact with stockpiles

MMI measures the fast moving coal on stacker-reclaimers

Stacker-reclaimer’s distance from the stockpile monitoring by using Echomax XPS-30 ultrasonic transducer instruments

Machine long travel monitoring by sensor (Hengstler AC61 SSI multi-turn encoder)

Monitoring the speed of diesel locomotive by sensor

Stacker-Reclaimer position monitoring of luff, slew and long travel by using Hengstler AC61 series encoder

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LIST OF PUBLICATIONS

International Journals:

1. **Ojha, S.,** Pal, B. K., Biswal, B. B. and Sarangi, D. (2014): Performance Monitoring of Vibration in Belt Conveyor System, International Journal of Engineering Research and Applications, Vol. 4, No. 7, pp. 22-31.

2. **Ojha, S.,** Pal, B. K., Biswal, B. B. (2015): OEE as an Indicator for Performance Measurement in Coal Handling Plant, International Journal of Innovative Science Engineering Technology, Vol. 2, Issue 9, pp. 103-110.

3. **Ojha, S.,** Pal, B. K., Biswal, B. B. (2015): Minimizing the Breakdown in Belt Conveyor System of Coal Handling Plant, SSRG International Journal of Mechanical Engineering, Vol. 2, Issue 9, pp. 1-4.

4. **Ojha, S.,** Pal, B. K., Biswal, B. B. (2015): Methodology for Operational Improvement in Side Arm Charger of Coal Handling Plant – A Theoretical Review, Journal of Quality Technology (Communicated & under Review).

Conference:

1. **Ojha, S.,** Pal, B. K., Biswal, B. B. (2014): Failure analysis of belt structure in Coal Handling Plant- A Case study" 1st National conference on Mining-Recent Advance, Challenges and Scenario Beyond 2015 (MRACSB- 2015) at Institute of Engineers, Rourkela chapter, Nov 8-9, held at Rourkela.