NDE2002 predict. assure. improve.
National Seminar of ISNT
Chennai, 5. – 7. 12. 2002
www.nde2002.org

Application & Implementation Of Residual Life Assessment Techniques For Coal Handling Plant

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Abstract

In the thermal power plants maximum requirements of fuel is a coal. The handling of this fuel is a great job. To handle the fuel i.e. coal, each power station is equipped with a coal handling plant. Maintenance of Critical Equipments for Coal Handling Plants (CHP) of Thermal Power Stations is typical job. The failures of these equipments have led to high maintenance and operation costs. Assessing the condition and remaining life of coal handling plant components is necessary to optimize inspection and maintenance schedules

Generally Non Destructive Testing (NDT) techniques adopted in the Residual Life Assessment (RLA) of power plant components like Boilers, Headers, Steam lines, Turbines, Feed water Heaters and Condensers. The reason for inspection depends on the component and its effect on plant operation. But one of the main and major systems of thermal power plant is coal-handling system. No such efforts are carried out to assess the life of coal handling plant component.

This paper summarizes some of the major aspects of RLA for coal handling plant. The concept of NDT, discussed in this paper for Coal Handling Plant is to offer significant benefits. Guidelines for implementation of RLA in CHP are also discussed in this paper.

Keywords: Coal Handling Plant, Crushers, Wagon Tipplers, Ropeway, Conveyor Structures, Ultrasonic, Fatigue Life Prediction, S-N curve, Strain life

1.0 INTRODUCTION: -

To maintain an efficiently operating unit and avoid failure of critical equipment, it is necessary to assess the condition and remaining life of that equipment. There are varieties of critical equipments components in Coal Handling Plants. These components require routine inspection to ensure their integrity. The purpose of the inspection is to identify any degradation in the integrity of the systems during their service life and to provide an early warning in order that remedial action can be taken before failure occurs. Conventional methods in CHP for identifying the presence of such damage are often " visual" methods. And there is no scientific approach for calculating Remaining Life of Equipment. For each of these components, there can be different types of flaws and damage. This may include cracks, pitting, material degradation, etc. Because of this combination of component types and defect types, several types of NDT methods have to be implemented in CHP.

A careful selection of methods is necessary for effective RLA. It is essential to identify the critical areas where failures are likely to occur and select suitable NDT techniques for detection of such failures. Based on design criticality, past experience and previous failure information, suitable approach in inspection methodologies can be adopted.

2.0 IMPORTANCE OF RLA FOR CHP: -

The basic layout of Coal Handling Plant is shown by block diagram. Generally the coal is received to CHP by four modes. These modes are railway, roadway, airway (by ropeway direct from coal mines) and ship transport. Those CHP are near coal mines receives coal by roadway and airway in addition to railway. The CHP, which is near sea, receives coal from ship in addition to railway. The railway transportation is generally use by all CHP. The coal is unloaded at various unloading station as per receiving mode and transported by conveyors to crushing and screening plant via transfer house (See Fig. No 1). After crushing required quantity of coal is transported to bunker via transfer house and remaining coal is stored in stockyard. This coal is reclaimed as per requirement. From the bunker the coal flows through coal mills to boiler furnace. The main aim of CHP to maintain level of coal in bunkers for smooth coal supply to boiler and maintain appropriate stock of coal.

There are different streams in coal handling plant, which are operated as per unloading units. The unloading devices, which are used to unload coal by railway, are known as wagon tipplers. The streams, which are related with these tipplers, are main streams. Generally there are two streams. One stream is used for bunkering and one is used for stacking. But two streams running are required for few times. Other streams are used as supporting stream. The streams, which receive crushed coal from all streams and supply coal to bunkers, are also important streams. One stream of these streams can be kept as stand by. But due to ageing of the coal handling plants the capacity of CHP's are reduced. So keeping of stand by is carried only when one of the boilers is kept under shutdown. In this period preventive maintenance is carried out of one of the main stream. If at the same time breakdown occurs in a machine in other stream, which interrupt the

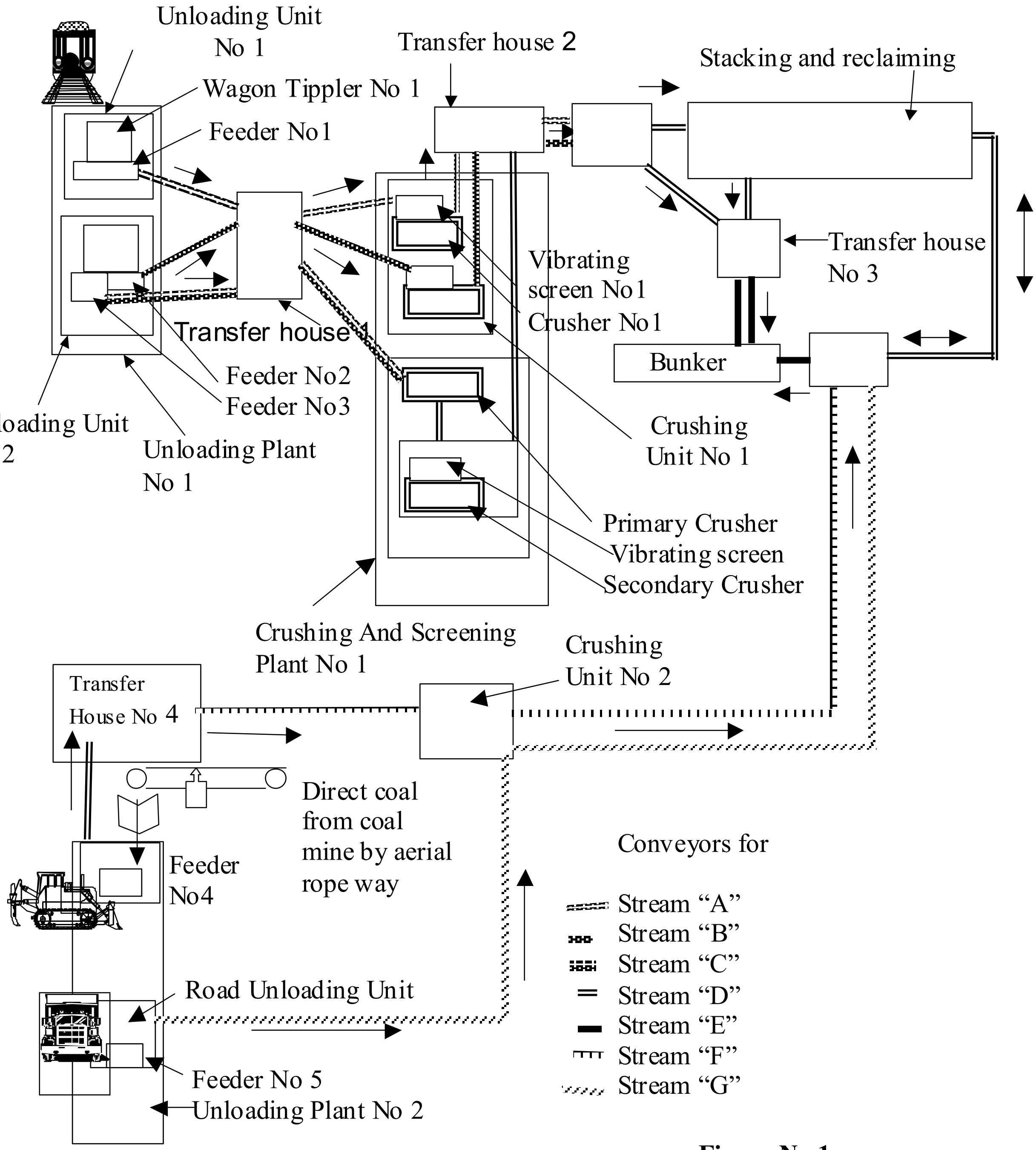
Unloading Unit No 1
Wagon Tippler No 1
Feeder No1
Transfer house 2
Stacking and reclaiming
Transfer house 1
Vibrating screen No1
Crusher No1
Transfer house No 3
Bunker
Feeder No2
Feeder No3
Unloading Unit No 2
Unloading Plant No 1
Crushing Unit No 1
Primary Crusher
Vibrating screen
Secondary Crusher
Crushing And Screening Plant No 1
Crushing Unit No 2
Transfer House No 4
Direct coal from coal mine by aerial rope way
Feeder No4
Conveyors for
Stream "A"
Stream "B"
Stream "C"
Stream "D"
Stream "E"
Stream "F"
Stream "G"
Road Unloading Unit
Feeder No 5
Unloading Plant No 2

Figure No 1

coal supply to boilers. Due this loss of generation will occur. The RLA will help to choose proper shutdown of stream to avoid further problems.

Some of the CHP's are now days are operating beyond their design lives. Working conditions in CHP are dusty, dirty and often wet conditions. So there is a constant quest to improve machine uptime and avoid unplanned maintenance. A plant, which supply of coal to boilers having capacity of 750 tones per hour failed to fulfill need will loss generation of 0.6 MU for one hour. This cost 1.20 Core of Rupees.

The life prediction approach will enable repair, up gradation, replacements of necessary components and extension of life of remaining components. This approach is advantageous, in terms of economy, to continue operating the aged plant by extending their lives for reasons of high construction cost.

3.0 OBJECTIVES OF RLA: -

The main objectives of RLA for CHP should be as follows.

1. Establishing of NDT in-situ technique.
2. Establishing method for planning the requirement of long lead items based on RLA.
3. Selection of stream for shutdown purpose based on RLA.
4. Prediction of impending failures of critical plant components like Crusher Rotors, Conveyor Pulley Shafts, in real time resulting in enhanced safety, operational reliability, availability, and maintainability.
5. Establishing life prediction approach to enable repair, up gradation, replacements of necessary components and extension of life of remaining components

4.0 R.L.A. IMPLEMENTATIONS: -

The steps for implementation of "Residual Life Assessment " are given below.

1. Detection of critical area/Equipments,
2. Defect Identification
3. In-Situ Examination of component
4. Fatigue Life Prediction

4.1 DETECTION OF CRITICAL AREA/EQUIPMENTS: -

In CHP the equipments which performance effects directly on plant operation and plant performance are known as Critical Equipment. It is important to identify the critical equipment of CHP. Crushers, Wagon Tippler, Bunker Feeding Conveyors and Feeders are critical equipments. To maintain an efficiently operating unit and avoid failure of critical equipment, it is necessary to maintain the critical parts of that equipment. So it is also important to identify the critical parts. The parts directly affect the performance of equipment performance and operations are known as critical parts of equipments.

4.1.1 CRUSHERS: -

The combination of impact and attrition crushing is main principle of crushers used in CHP. In this type of crushing first coal is break due to impact and further scrub between two hard surfaces to get desired coal size. Some crushers are work only on principle of impact crushing. Generally these crushers are used before final crushers.

The output size of coal affects the performance of CHP. Naturally these two hard surfaces of crusher are critical parts. One of these surfaces are known as grinding plates and other may known as rings, hammers etc. The linkage between crusher rotor and drive assembly are also critical parts. The crushing will stop due to failure of these linkages.

4.1.2 WAGON TIPPLERS: -

In CHP generally there are two types of wagon tippler. They are known as rota type and rotary type. The main difference between these tipplers is that rotary type tippler is having floating barrel and rota type tippler turns between two bearings.

The drive linkages are undergoing of cyclic loading and failure of these linkage stop the equipment operation. Due to this unloading of coal cars affects, which drop the performance of CHP.

4.1.3 BUNKER - FEEDING CONVEYORS: -

CHP are having number of conveyors but bunker-feeding conveyors are playing vital role. The main aim of each CHP is to maintain bunker levels for smooth coal supply to boilers. As these conveyors feeds the bunker their performance affects CHP performance. The drive linkages consist of gearbox and couplings. Failure of any part of the linkage will stop operation of feeding bunker level. So these parts are critical parts of bunker feeding conveyors. The conveyor pulleys are also critical parts.

4.1.4 FEEDERS: -

The performance of feeders affects the efficiency of CHP. The feeders used in CHP are Apron Feeder, Vibrating Feeders, Roller Screens and Vibrating Screen Feeders etc. Generally vibrating feeders, which are used, are of electromagnetic type. The springs and coils and suspension rods are the critical parts. Weak coil springs that are not generating sufficient accelerating forces can also cause low speed and reduce the performance. In vibrating screen feeder have critical part like beam and its members, drive linkages etc. Apron Feeders is sturdy machine the main critical parts are pans, chain and rollers. The roller screens have critical parts in drive linkages.

4.1.5 ROPEWAY: -

Transport by ropeway has an important role in coal handling due to its easy operation, maintenance, long service life and low cost per ton. The ropeway is normally aligned "as the crow files " (smaller investment cost), overcoming most topographical obstacles, because of its high above the ground; also, it does not interfere with animals and persons nor requires the splitting up of properties and the acquisition of extensive rights of way. Steel wire ropes are extensively used in Aerial ropeway for haulage, track and hoisting purposes. Failure of these ropes will cause stoppage in coal transportation.

4.2 DEFECT IDENTIFICATION: -

Coal Handling Plant components are subjected to work in severe working conditions and their behavior vary on different environmental and nature of service they are subjected to work. Depending upon the actual operating and environmental condition, material properties of CHP equipments degrade as a function of service life due to one or more of the time dependent material damage mechanism such as fatigue, corrosion, erosion etc.

4.2.1 FATIGUE FAILURES: -

Fatigue is the main cause of failure of machine parts in service, in mechanisms and structural elements. Repeated cycling of the load causes metal fatigue. It is a progressive localized damage due to fluctuating stresses and strains on the material. Metal fatigue cracks initiate and propagate in regions where the strain is most severe. Metal fatigue is a significant problem because it can occur due to repeated loads below the static yield strength. This can result in an unexpected and catastrophic failure in use. Collapses by fatigue are especially dangerous because they are unpredictable, giving no prior notification of the imminent failure. They occur suddenly and show no exterior plastic deformations. They are fragile failures, which display two well-separated zones [1], a dark polished zone showing obvious ductile cleavage, which happened smoothly, and a rough shinier zone where the final break is localized after surpassing the fatigue-reduced material strength.

In CHP generally fatigue failure are observed in Conveyor structures, Conveyor pulleys, Crusher Rotors, Motor shafts, Suspension Bars and Arms of Crushers. The failure may be due the discontinuity, manufacturing defects, improper maintenance or other causes. A failure analysis can determine the cause of the failure. Table No 1 show the components, which are failed due to the fatigue.

4.2.2 STRESS CORROSION CRACKING: -

Corrosion can occur at different location and in different forms. Stress corrosion cracking is an insidious [2] type of failure as it can occur without an externally applied load or at loads significantly below yield stress. Thus, catastrophic failure can occur without significant deformation or obvious deterioration of the component. Pitting is commonly associated with stress corrosion cracking phenomena.

Aluminum and stainless steel are well known for stress corrosion cracking problems. However, all metals are susceptible to stress corrosion cracking in the right environment. Structures subjected to fluctuating service loads are vulnerable to fatigue damage. Conveyor structures, Transfer Chute Liners, Grinding jib of crushers are failed due to reduction in thickness due to wearing of surface and pitting. Table No 1 show the components, which are subjected to stress corrosion.

Table No 1

Component	Type of defect	Affecting factor	Reasons
Transfer Chute Liners, Grinding jib of crushers.	Reduction in thickness due to wearing of surface	Continuous coal flow	Friction between coal and component
Transfer Chute Liners, Grinding jib of crushers.	Development of cracks, holes	Impact of coal	Crack generated from the holes for fixing of bolts
Transfer Chute Liners, Grinding jib of crushers	Pitting	Corrosive component of coal	The wet coal when flows through then chances are more.
Conveyor structures	Reduction in thickness due to wearing of surface and pitting	Corrosive component of coal	The acumination of coal on structures
Conveyor structures	Catastrophic fracture failure	Cyclic Loading	A result of manufacturing fabrication defects or localized damage in service,
Crusher Rotors, Suspension Bars, Arms Motor shafts	Development of cracks Development of cracks	Impact of coal Cyclic loading	Due to internal flaw Fluctuation in load.
Bearings	Development of cracks in the races	Improper loading,	Due to internal flaw
Conveyor pulleys Drive foundations	Due to End disc failure Bolt failure, Frame failure	Cyclic loading Cyclic loading	Failure of the weld between the hub and the end disc in welded-in hub designs. A result of manufacturing fabrication defects or localized damage in service,
Conveyor pulleys	Failure of locking assembly	Cyclic loading	Failure of locking bolts
Wire ropes of Aerial Ropeway	Due damage in strut	Cyclic loading	Due to weak area of strut

4.3 IN SERVICE EXAMINATION: -

Periodic in service examination is necessary for critical components. In non-destructive testing, crack detection plays an important role. Various NDE techniques like Ultrasonic thickness gauging, Ultrasonic flaw detection, Penetrant testing, Fluorescent magnetic particle testing, can be used. (See Table No 2) Specialized techniques such as Digital Radiography; Acoustic Impact Techniques, Thermograph can be used for in service examination.

Table No 2

Measurement		Equipment	
Parameter	**Instrumentation**	**Positions**	**Description**
Thickness	Ultrasonic [4] thickness gage [5] like " Nova TG2"	Surface	Transfer Chute Liners, Grinding jib of crushers, Conveyor structures etc.
Thickness	Digital Radiography [6]	Surface	Transfer Chute Liners, Grinding jib of crushers, Conveyor structures etc.
Flaw	Ultrasonic [7] Flaw Detector [5] like "Quantam TE"	Surface/inside	Crusher Rotors; Jack shaft, Grinding jibs; Suspension Bars, Arms, Sprocket Tiers Drive Foundations etc.
Flaw	Acoustic Impact [8] Technique	Surface/inside	Crusher Rotors, Bearings
Flaw	Magnetic [9] Flaw Detector [10] like "MD20 Wire Rope Tester"	Surface/inside	Wire ropes of Aerial Ropeway
Flaw	Weld regions by x-ray diffraction	Surface/inside	Drive Foundations
Thickness	Ultrasonic [11] thickness gage	Surface	High pressure pipe line of hydraulic system of Wagon Tippler

4.4 FATIGUE LIFE PREDICTION: -

Metal fatigue is a process which causes premature failure or damage of a component subjected to repeated loading. The fracture of the machine parts occurs at stress very much lower than their ultimate [12] statical strength. A fatigue failure usually has its origin in some surface of internal imperfections in the form of minute inclusions. Localized high stresses are induced in the material because of these discontinuities. Under cyclic loading micro flaws or small cracks begin to appear at these location. This first stage is known as initiation. Fatigue crack are appear after certain load cycles at nominal stress levels at nominal stress levels, which are often below the tensile strength of the material. In next stage, which is known as "Propagation" these cracks, tends to extend across the section if the cyclic loading is repeated. A stage will be reached when the net section is reduced so much that fracture takes place. The last stage is final rupture, which is separation into two, or more parts by a single load application are known as "Fracture". The philosophy to predict [13] fatigue life is based on S-N curves, load spectrum simulating local material state using stabilized σ -ε loop, Local strain approach and σ -N curve.

4.4.1 FATIGUE LIFE PREDICTION ANALYSIS METHODS: -

There are four methods for analysis of fatigue life prediction, which will be useful while caring RLA in CHP.

1. Stress Life Method (based on S-N curves)
2. The Fracture Mechanics Method (based on the Paris-Erdogan theory together with empirical da/dN-curves.)
3. Strain Life Method (based on ε -N curve)
4. Multiaxial Life Prediction Methods (based on Tresca, Von Mises and Rankine theory)

4.4.1.1 STRESS LIFE METHOD (BASED ON S-N CURVES): -

The S-N curve shows the number of cycles, N_f, which a test specimen can resist before it breaks. All cycles in a test have a fixed stress range or amplitude, and measurement on one specimen gives one point on the curve. The general trend is, of course, that the lower the stress range Δ S, the longer the lifetime N_f. But beyond this, the details of the curves depend on several physical factors and may be given different mathematical representations. See Figure No 2

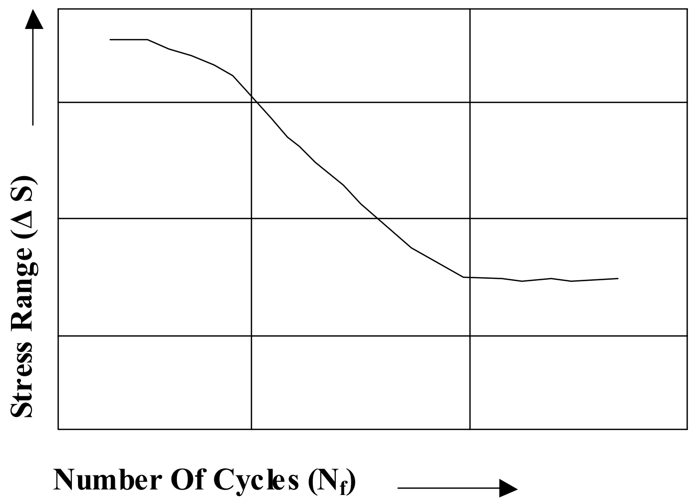

Figure No 2

The Wohler S-N curves mathematically [14] represented as $N = C/\Delta S^m$ where C is intercept of S-N curves, m is slope of S-N curves and S is stress range. The Palmgren-

Miner method covers prediction of the whole life of an element, that is, both the initiation and the propagation phase. When the analytical form of the S-N curve is combined with the stress-range probability distribution, the fatigue life may be expressed in a closed, mathematical form. This approach can be used in transfer chutes and conveyor structures.

4.4.1.2 THE FRACTURE MECHANICS METHOD: -

This approach is concerned with the initiation and propagation of cracks. Fracture mechanics is based upon the fundamental assumption that all structures, whether new or in service for many years, contain minute flaws, which, under the proper conditions, can cause [21] fracture. In order to determine the residual strength of a structure, the relationship between the crack tip stress field and crack length must be established. These relationships can be established by following theory.

1. Griffith's Theory
2. Irwin Theory
3. Paris Theory

These theories will be useful for drive foundations of machines, transfer chute liners.

4.4.1.3 STRAIN LIFE METHOD (BASED ON ε -N CURVE): -

This method is usually considered in initiation approach. It is used when the strain is no longer totally elastic but has a plastic component. Based on observation that, in many components the response of the material in critical location is strain or deformation dependent. This is useful for ductile material and low cycle fatigue analysis. Low cycle fatigue is the repeated cyclic loadings that cause significant plastic deformation in a material and may cause fatigue cracking after a relatively small number of cycles-hundreds or thousands. Low cycle fatigue typically occurs as a result of repeated localized yielding near stress raisers, such as holes, fillets, and notches, despite the elastic deformation occurring over the bulk of the component. If a sufficiently high strain level is reached, yielding may occur before the maximum strain is reached on each cycle of loading. Stress amplitude usually varies; if it increases, the material [17] is said to cyclically harden, if it decreases, the material is said to cyclically soften. However, this behavior tends to stabilize such that the variation in the stress amplitude is small after an initial period of transient hardening or softening. Once the behavior is stabilized, a closed stress-strain hysteresis loop is formed during each strain cycle.

These theories will be useful for grinding jib of crushers, transfer chute liners.

4.4.1.4 MULTI-AXIAL LIFE PREDICTION METHODS: -

The majority of components and structures are subjected to multi-axial cyclic loading condition resulting in bi-axial and tri-axial stresses. To predict the fatigue life of such components and structures this method is useful. Following theories are useful for this type of approach.

1. The maximum shear stress theory (Tresca)
2. The distortion energy criterion theory (Von Mises)
3. Maximum principal stress theory (Rankine)

Knowing the three-dimensional stress and strain component, the application of equivalent stresses and strain can be applied to fluctuating loading. The equivalent stress and strains can be applied to fluctuating loading, which can be derived by adapting the Von Mises and Tresca theory.

These theories will be useful for crusher rotors, jack shaft and motor shaft..

4.4.2 RESIDUAL LIFE ASSESSMENT TECHNIQUE: -

Methods of Residual life assessment are dependent upon a multiplicity of factors. The Residual life assessment depends upon material properties, usage history, and the damage intrinsic to the material component itself. Knowledge of the geometry and location of the flaw and their interaction, if any, allows determination of component life. Table No 4 shows the RLA technique, which will be applicable while caring RLA in CHP.

Table No 4

Description	Parameter	Measurement	Theory	Method
Transfer Chute Liners, Grinding jib of crushers, Conveyor structures, Drive Foundations etc	Thickness	Stress	Palmgren-Miner	Stress-Life
	Flaw	Crack Length	Irwin	Fracture Mechanics
	Drilled Hole	Radius	Coffin and Monson	Strain-Life
	Drilled Hole	Crack Length	Von-Mises	Von-Mises
	Flaw	Radius	Von-Mises	Multi-axial
Crusher Rotors; Jack shaft,	Flaw	Crack Length	Irwin	Fracture Mechanics
	Flaw	Radius	Von-Mises	Multi-axial

5.0 CONCLUSION: -

Visual inspection of CHP Equipments for the in service inspection had deficiencies. The non-destructive examination of CHP Equipments will play a vital role and the data obtained from non-destructive investigations at periodic interval will assist in developing future in determining CHP Equipments extension/premature retirement criteria.

Residual life assessment will help in identification of critical components that require replacement/modification.

The implementation of RLA will ensure continued reliable operation of the CHP. It will minimize forced outage and avoid catastrophic damages. It will ensure safe environment. The approaches will categories critical and non-critical components.

This approach will enable repair, up gradation, replacements of necessary components and extension of life of remaining components of CHP.

This approach will be advantageous, in terms of economy, to continue operating the aged plant by extending their lives for reasons of high construction cost. RLA will be a powerful tool, based in continuum mechanic and the finite element method, which will allow accurate predictions on fatigue behavior of metallic components of CHP.

The extent of investigation is required to predict the remaining life of most of the components with reasonable accuracy.

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Caption For Table: -

Table No 1: Component Defects And Its Reasons

Table No 2: In Service Inspection For Equipments

Table No 3: Methods for RLA

Caption For Figure: -

Figure No 1: Block Diagram Of Coal Handling Plant

Figure No 2: S-N Curve