Residual Life Assessment

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***Abstract*-Predicting the residual life of plant equipment that has been in service for 15 to 25 years or more is a major concern of many industries. This research paper reviews the reasons for increased concern for residual-life assessment and the general procedures used in performing such assessment.**

Keywords- Residual,RLA,steel,life

I. INTRODUCTION

Predicting the remaining operating life of plant equipment that has been in service for many years is a problem faced by many industries and many power plants. The problem is especially for those companies whose plants have been in service for 15 to 25 years or more. This research paper gives general introduction to the topic of residual-life assessment. Analysis of reliability data plays an important role in the maintenance decision making process. The accurate estimation of residual life of in components of equipment and system can be great asset when planning the preventive maintenance. To get high operational availability and stability in maintenance for develop life extension of equipment. It is essential to correct assessment of residual life of equipment. A lot of confusion in the residual life assessment (RLA) technology for service exposed machine components because simple metallurgical analysis has often been passed on as RLA to machine users by numerous independent consultants including repair and overhaul businesses. These metallurgical analysis based RLA reports provide a recommendation for further use without providing any substantial quantitative basis for life extension. In the current economic and political climate, many companies cannot afford to replace existing plants or major components and must find a way to safely extend their operating life. For them, reliable methods for predicting residual life are a must. Accurate, reliable predictions of residual life provide a basis for timely, safe, and economic replacement or repair of key components; they can help to maximize a plant's usefulness by:

- establishing a sound, defensible basis for extending operating life,
- reducing costly unscheduled outages caused by in-service failures,
- and eliminating unnecessary replacements.[1]

Thus, proper implementation of residual-life prediction methodology allows the continued use of plants that might otherwise be retired from service unnecessarily. This can mean lots of net savings to some companies.

II. WHAT IS RLA?

Equipment was designed to work under certain conditions and has certain expected life. If these equipments are operated under harsher conditions then their useful life is short. For the estimation of the residual lifetime the maximum expected lifetime, assuming that the equipment will be operated under same conditions, has to be found out. The expected lifetime is a function of the operating conditions. In dependence of the average load level it can get shorter for higher load conditions. The residual lifetime can be defined as the difference between the expected lifetime and the actual age. For general mechanical equipment the relationship between expected life and load conditions can be described as (Figure1)

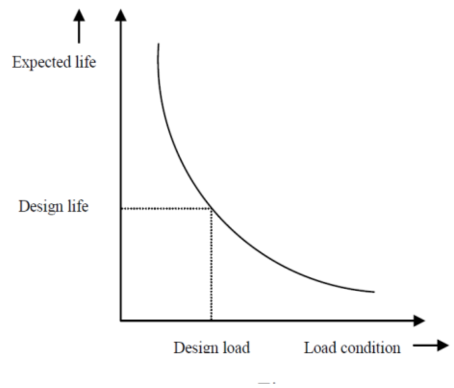

Figure 1 . Relationship between expected life and load conditions

III. METHODOLOGY SUGGESTED FOR IMPLEMENTATION:

The mechanical equipments are normally expected to fail due to aging or wear. Sometimes random failures occur due to causes which are external to the system. The equipment is repaired and brought back to working condition.

The record of the conditions under which the equipment has worked over the past period is extremely important for RLE studies. This forms the basis and this information coupled with other maintenance records will be very helpful. The general steps followed for carrying out RLE studies are -

(a)Study of past performance data and review of O&M records e.g. loading conditions, number of tripping failures, repairs/replacements etc.

(b)Assessment of present condition of the equipment, E.g. efficiency and operating parameters.

(c)Assessment of remaining life of various equipment parts by conducting residual life estimation (RLE) studies.

(d) Identification of components requiring replacements, repairs, up-gradations/retrofitting.

(e) Formulation of R&M/Life Extension scheme covering complete scope of works.

IV. VARIOUS TECHNIQUES USED FOR ASSESING PRESENT CONDITION

The equipment which undergoes RLA studies, is completely dismantled and each and every part is inspected for damage and wear out. The parts which are critical for proper operation of the equipment are inspected thoroughly using various Non Destructive Evaluation Techniques. They are -

1. Non destructive examination (NDE) technique e.g., dimensional measurement, optical observation, and ultrasonic, eddy current, X-ray.
2. Metallographic examination, e.g., through-section, outer surface, and plastic replication techniques.
3. Risk-based inspections (RBI).

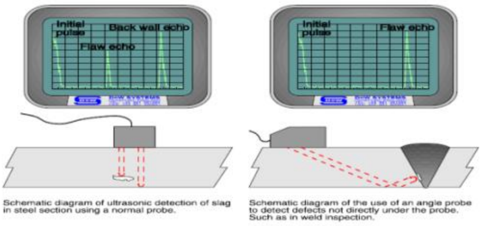

Figure 2 . Ultrasonic flaw detection[9]

1. NDE TECHNIQUE:-

Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage. The terms Non destructive examination (NDE), Non destructive inspection (NDI), and Non destructive evaluation (NDE) are also commonly used to describe this technology. Common NDT methods include ultrasonic testing, magnetic-particle inspection, liquid pentrant testing, remote visual inspection (RVI), eddy-current testing.

1.1 A Brief Description Of NDT Techniques:-

1.1.1 Ultrasonic Flaw Detection

This technique is used for the detection of internal and surface (particularly distant surface) defects in sound conducting materials. The principle is in some respects similar to echo sounding. A short pulse of ultrasound is generated by means of an electric charge applied to a piezo electric crystal, which vibrates for a very short period at a frequency related to the thickness of the crystal. In flaw detection this frequency is usually in the range of one million to six million times per second (1 MHz to 6 MHz). [9]See figure 2.

1.1.2 Eddy Current Testing

The main applications of the eddy current technique are for the detection of surface or subsurface flaws and coating thickness measurement. The technique is sensitive to the material conductivity, permeability and dimensions of a product. Eddy currents can be produced in any electrically conducting material that is subjected to an alternating magnetic field (typically 10Hz to 10MHz). The alternating magnetic field is normally generated by passing an alternating current through a coil. The coil can have many shapes and can between 10 and 500 turns of wire. The magnitude of the eddy currents generated in the product is dependent on conductivity, permeability and the set up geometry. Any change in the material or geometry can be detected by the excitation coil as a change in the coil impedance. The simple coil comprises a ferrite rod with several turns of wire wound at one end and which is positioned close to the surface of the product to be tested. When a crack, for example, occurs in the product surface the eddy currents must travel farther around the crack and this is detected by the impedance change.[9] See figure 3.

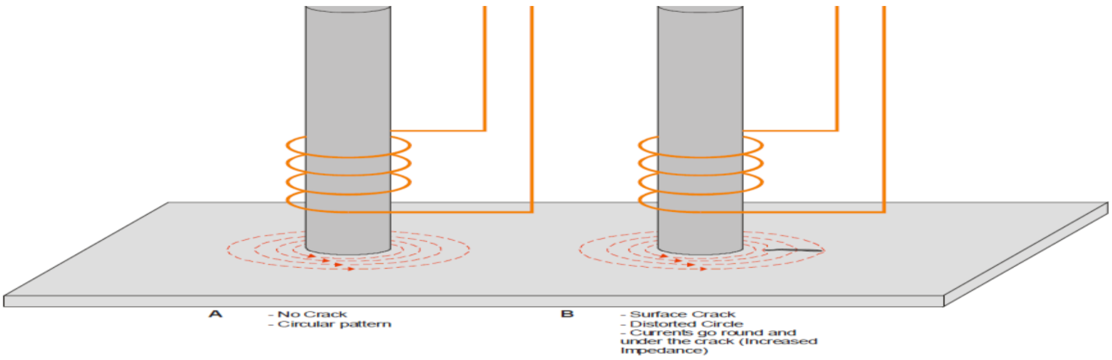

Figure 3 . Coil with single winding [9]

1.1.3 Dye Penetrant Testing

This method is frequently used for the detection of surface breaking flaws in non ferro-magnetic materials. The subject to be examined is first of all chemically cleaned, usually by vapour phase, to remove all traces of foreign material, grease, dirt, etc. from the surface generally, and also from within the cracks. Next the dye (which is a very fine thin oil usually dyed bright red or ultra-violet fluorescent) is applied and allowed to remain in contact with the surface for approximately fifteen minutes. Capillary action draws the dye into the crack during this period. The surplus dye on the surface is then removed completely and thin coating of developer is sprayed. After a further period (development time) the developer draws the dye out of the crack, to form a visual, magnified in width, indication in good contrast to the background. The process is purely a chemical.[9] See figure 4.

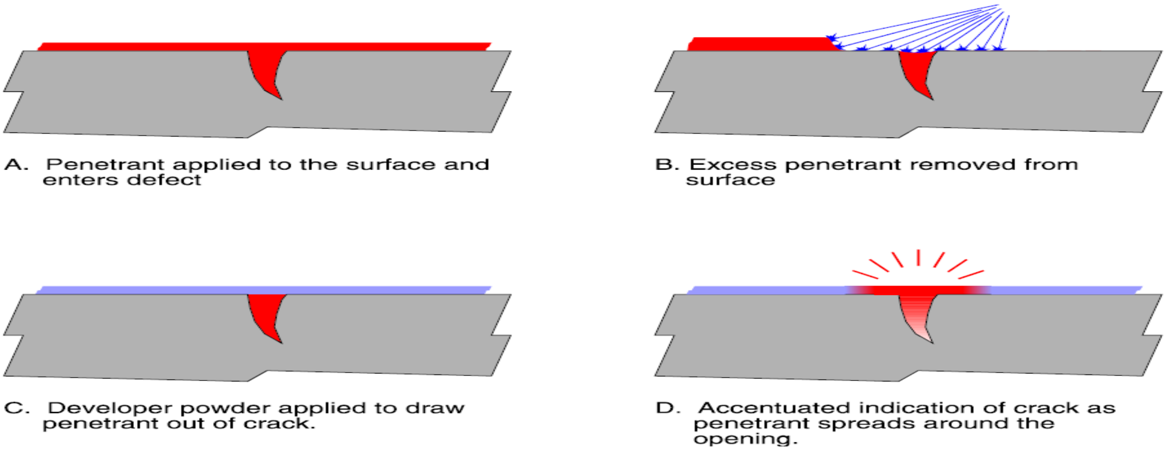

Figure 4 . Illustration of Dye Penetrant Testing [9]

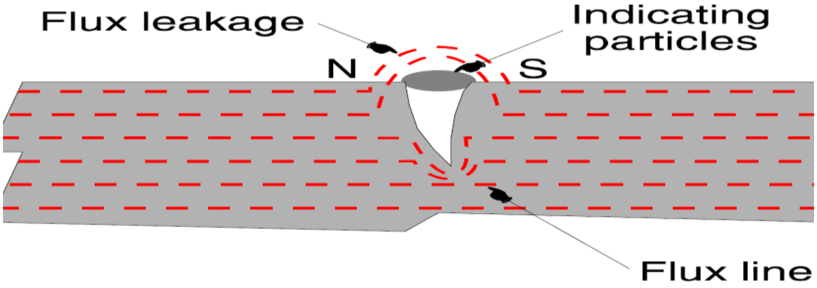

Figure5. Inspection of magnetic particles [9]

1.1.4 Magnetic Particle Inspection

This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferritic steel and iron.The principle is to generate magnetic flux in the article to be examined, with the flux lines running along the surface at right angles to the suspected defect. Where the flux lines approach a discontinuity they will spray out in to the air at the mouth of the crack. The crack edge becomes magnetic attractive poles North and South. These have the power to attract finely divided particles of magnetic material such as iron fillings. Usually these particles are of an oxide of iron in the size range 20 to 30 microns, and are suspended in a liquid which provides mobility for the particles on the surface of the test piece, assisting their migration to the crack edges. However, in some instances they can be applied in a dry powder form. The particles can be red or black oxide, or they can be coated with a substance, which fluoresces under black light. The object is to present as great a contrast as possible between the crack indication and the material background. [9]See figure 5.

1.1.4 Radiography

This technique is suitable for the detection of internal defects in ferrous and nonferrous metals and other materials. X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes, are penetrating radiation which is differentially absorbed by the material through which it passes; the greater the thickness, the greater the absorption. Furthermore, denser material gives greater absorption. X ray and Gamma rays also have the property, like light, of partially converting silver halide crystals in a photographic film to metallic silver, in proportion to the intensity of the radiation reaching the film, and therefore forming a latent image. This can be developed and fixed in a similar way to normal photographic film. Material with internal voids is tested by placing the subject between the source of radiation and the film. The voids show as darkened areas, where more radiation has reached the film, on a clear background. The principles are the same for both X ray and Gamma radiography. In X-ray radiography the penetrating power is determined by the number of volts applied to the X-Ray tube - in steel approximately 1000 volts per inch thickness is necessary. In Gamma radiography the isotope governs the penetrating power and is unalterable in each isotope. [9]

An illustration of Radiography shows in figure 6.

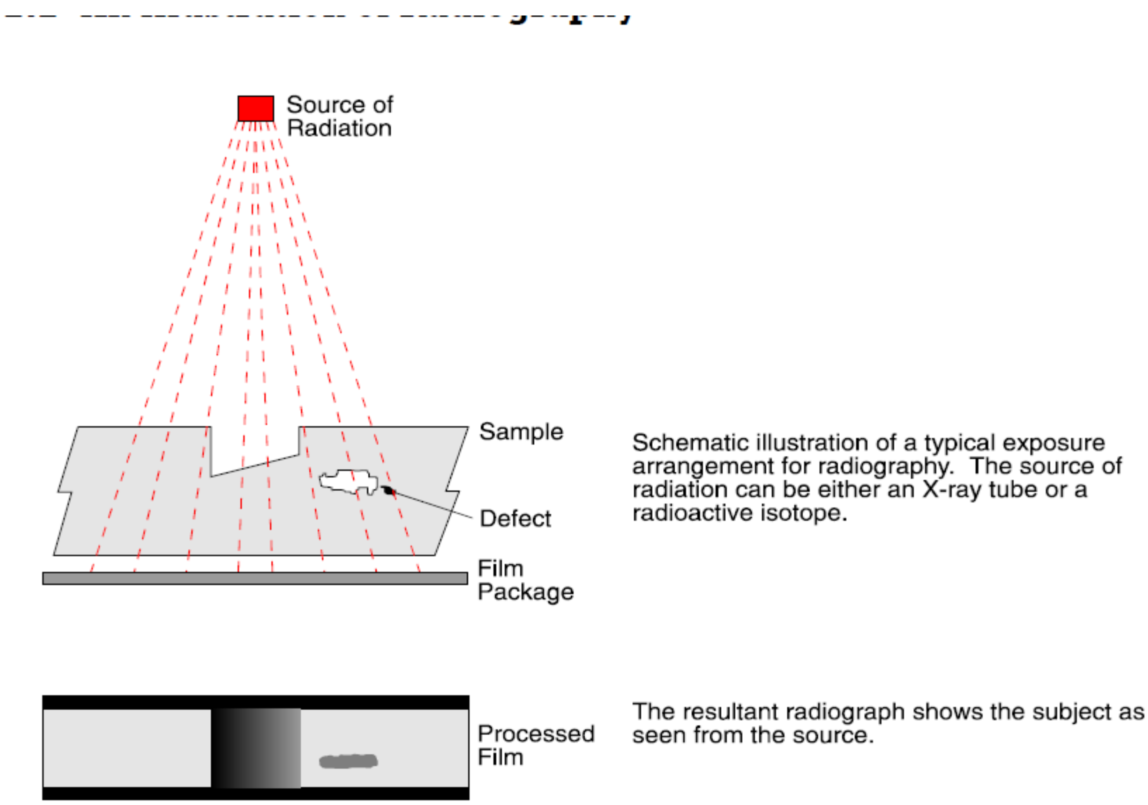

Figure 6 . An illustration of Radiography [9]

1.5 Visual Inspection

Basic principal is that check the specimen with normal eye or under light.

• Visual Inspection Equipment

1. Magnifying Glass
2. Magnifying Mirror
3. Microscope
4. Boro-scope
6. Video Image scope

2 METALLOGRAPHIC EXAMINATIONS:

2.1 Ferritic Steels

As far as this type of material is concerned, the aspects mainly considered valid as an index of creep exposure are:

2.1 Micro-structural phase evolution

2.2 Micro-void formation at grain boundaries

2.3 Evolution of carbides (eutectoid and ferritic fine precipitation)

2.4 Inter particle distance

2.1.1 Micro-structural phase evolution:-This aspect is mainly related to the effect of temperature and is not so strictly connected to load application. It is commonly accepted as a qualitative thermal degradation index shown through:

- tendency to pearlite/bainite spheroidisation

- coarsening of precipitates in the ferritic matrix and at grain boundaries,

- broadening of denuded zones (no precipitates) along grain boundaries.[4] see figure 7.

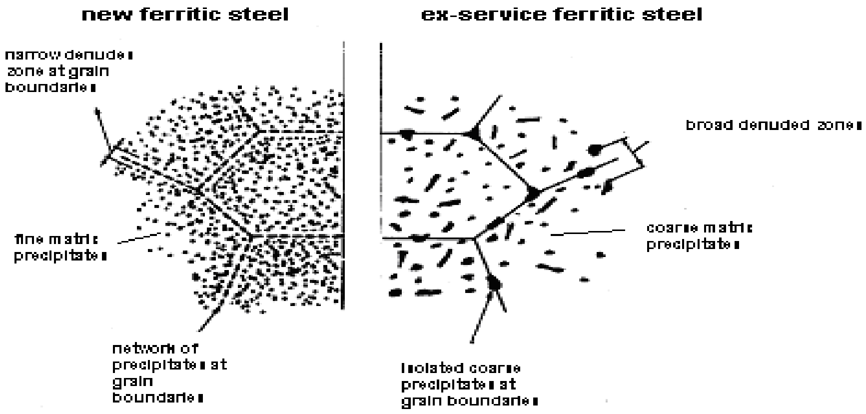

Figure 7 . Micro-structural phase evolution [4]

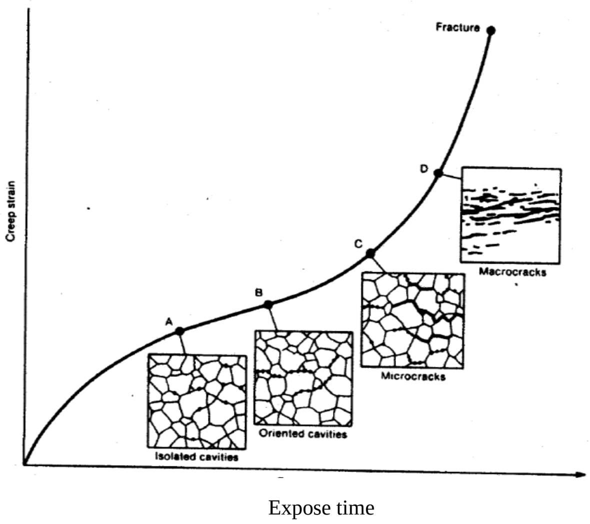

Figure 8 micro-voids formation [7]

2.1.2 Micro-voids formation at grain boundaries:-The principle is based on the fact that creep evolution of heat resistant steels is related to the appearance of cavities some time before rupture. These cavities gradually form micro-cracks by inter-linkage and at the end come to initiate the rupture. Size and density of the cavities increase as creep progresses from secondary to tertiary. Cavity size is largely dependent also on material type, however it is in the range of micron size (often also lower), therefore they are usually called "micro-voids" or "micro-cavities". Due to their small size, they cannot be detected by conventional NDT techniques such as PT, UT, MT, RT, and metallographic investigation is required. [4] see figure 8.

2.1.3 Carbide evolution:-Many significant studies have been conducted on the evolution of carbides present in steels due to creep exposure. Separation and coarsening of carbides is in general an index of material degradation due to creep exposure. The most important carbides are M3C Essentially cementite Fe3C but often including other metallic elements (in particular Mn), the content of these other elements is controlled by element tendency to partitioning among ferrite matrix and affinity to carbon for carbide formation.

2.1.4 Inter-particle distance:-The concept is strictly related to phenomenon of carbide coarsening and grain boundary area the microstructure transformation correspond in an inter-particle distance growth that can be statistically (roughly or more precisely) estimated.

2.2 Techniques Applied For Investigation On In-Service Components

The most of the studies done on correlation of material microstructure and creep exposure have been performed by means of metallographic specimen obtained from creep specimen after tests. A large improvement of the investigation on actual in service components has been obtained with the replica technique.

2.2.1 Replica investigation:-The technique is essentially the application of metallographic specimen preparation (grinding, polishing, and etching) to a limited area of the component that is required to investigate and the reproduction of the so prepared surface on a thin foil of polymeric material. If microstructure evolution is the target of replica examination, the removal of a thin layer of surface material (about 0.3-0.5 mm thickness reduction) is recommended so to avoid the external layer of decarburized material. The reproduction of prepared surface on plastic material is achieved by the softening of polymeric thin foil with adequate solvent followed by hardening of the same plastic material due to solvent evaporation. Replica can be observed with the utilization of an optical microscope, where standard magnification ranges from50 to 500 x (1000 x magnification can be achieved but often difficulties can be matched on focus optimization of replica surface).

2.2.2 Hardness:-Since the first study developed for the assessment of residual life in high temperature serviced components, attention has been paid to hardness value in order to find numerical correlation of the parameter with service and expected time of the component. In the research studies hardness has been measured through standard instruments as Vickers or Brinell indenter based, but for in plant direct monitoring of serviced component some instruments based on energy absorption during impact or indentation combined with ultrasonic measurements are available as correlation for standard unit conversion. Due to this fact it is thus possible to obtain also results directly from in-service components. Actually at the moment although hardness measurement in plant is a commonly applied technique during maintenance inspection (especially in combination with replica) the most of the published studies are based on laboratory measurement made on test specimens with standard hardness measurement techniques.[4]

2.2.3 Risk-Based Inspections (RBI):-The risk-based inspection (RBI) methodology was introduced by Chinese petrochemical enterprises from the beginning of this century, it has been put into practice fruitfully on the pressure-bearing systems of over 30 petrochemical plants, and the safety and economy of enterprise production have improved. In the past several outstanding problems found, helped in the development of RBI in China, for example, with respect to the problem of acceptable risk, the principle of "equal risk level", and similarly, the determination of inspection cycle, effectiveness of online inspection, relationship with statutory regulations and technical specifications, software introduction and improvement, etc., are used to get the definite suggestions.[4]

V. RESIDUAL LIFE ASSESSMENT

1. Using Damage Parameter

In high pressure and high temperature components, headers & steam pipes, the consequential damage mechanism is creep, which manifests itself in the form of cavities in the microstructure. The morphology (shape characteristics and orientation) of the cavities shows the status of the component in terms of its remaining life. The phenomenon of creep is guided by the factors such as temperature, stress, time and material properties. Given a material that is subjected to constant temperature and stress (pressure), creep damage evident in the microstructure will be a function of time (expended life fraction).

Fatigue Usage Fraction:-

The maximum stress developed due to thermal pressure. Take alternating stress range (S range), with the lower limit zero towards the max in the shut down condition, fatigue life usage fraction is obtained from S-N curve as

$$Uf = n/N$$

Where, n is the actual number of stress cycles experienced by the component, and N is the maximum number of stress cycles that the component can withstand.[8]

S-N Curve :-These curves represent the relationship between the stress Range and corresponding fatigue life

'N' measured in terms of number of stress cycles to failure. To develop these curves, fatigue tests are conducted in laboratory on representative samples. For each stress range different values of number of cycles till failure are obtained. S-N curves have been developed based on data of full size specimen of different types of connections. See figure 9.

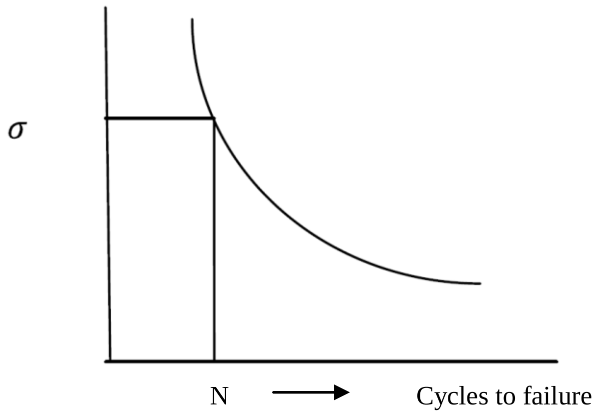

Figure 9. Stress to number cycle graph

Where stress range and N is is number of stress cycles to failure.

Creep Usage Fraction:- Maximum stress due to pressure and load condition, creep life usage fraction (Uc) is obtained from creep curve at operating temperature. Creep life usage fraction is given by the ratio t/tr.

Where t is total duration in hour and tr total time from s-t curve. [8]

Residual Life Estimation:-Theoretically, residual life fraction of component is given by

RLF = 1 – Uf – Uc.

However, due to many factors influencing fatigue and creep such as deviations from design during manufacture and operation, notches, surface finish, size of component and creep-fatigue interaction, which are not theoretically estimated.

Residual life fraction is given by:-

RLF = (½) – Uf – Uc.[8]

2.Oxide Scale Thickness Method

It is related to corrosion which are formed on the material. The severely corrosion affected area was examined with penetrating liquids and ultra sounds.

The Remaining Life is calculated based on the oxide scale measured with the optical microscope and or other non-destructive methods by using the following formulae:

Log X = 0.00022 P – 7.25

P = T (20 + log t)

X – oxide scale thickness in mils

P – T (20 + log t) [Larsen miller parameter]

T – temperature in 0 R (0 F + 460)

t- time in hour

Tr = t × Texp

Where Tr = reaming time in hours, Texp = running hours

VI. RENOVATION AND MODERNIZATION

Predictive maintenance is becoming more popular as a productivity tool. It helps to eliminate unscheduled downtime of equipment and reduce the overall cost of maintenance. The performance of equipment can be analyzed to determine its condition and predict when it will need attention. The concept of simple replacement of power equipment in the system, considering it as weak or a potential source of trouble, is no more valid in the present scenario of financial constraints. Today the paradigm has changed and efforts are being directed to explore new approaches/techniques of monitoring, diagnosis, life assessment and condition evaluation, and possibility of extending the life of existing assets. Renovation and modernization and life extension of equipment is one of the cost effective option for maintaining continuity and reliability. R&M is primarily needed to arrest the poor performance of the equipment which are under severe stress due to poor grid conditions, poor and inadequate maintenance and polluting environment. The methodology of implementation of R&M and life extension schemes and the essential inputs required for its successful implementation have been suggested.[3]

Need for Renovation and Modernization:

1) Deterioration in performance due to aging, poor maintenance etc.

2) Deterioration in performance due to design deficiencies, pollution etc

3) Non-availability of spares due to obsolescence.

Objective of Renovation and Modernization**:**

a) To arrest the deterioration in performance.

b) To improve the availability, reliability, efficiency and safety of the equipment.

c) To regain lost capacity

d) To extend the useful life beyond designed life of 25 years.

e) To save investments on new equipment

f) To meet environmental pollution norms and to have more effective pollution control.[3]

In practice, residual-life assessment may be applied to a single component, a major subsystem, or an entire plant. A systematic assessment procedure needs to be developed to prioritize, select, and integrate appropriate methods tailored to the specific problem under consideration. The procedure would identify the likelihood of success and the costs/benefits for applying a given method. It would provide a framework for:

- assessing the system to identify critical components,
- selecting measurement, sampling, and computational methods,
- making life-extension recommendations, and
- Evaluating the economics of implementing those recommendations.

VII. CONCLUSION

In this paper, the overall concept of about residual life estimation is presented. Various techniques useful for finding present condition of component are studied. The methodology of Residual Life Estimation is discussed. The importance of past data and various damage causing mechanisms is shown.

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