Assessment of Residual Life of Engineering Component

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***Abstract*-A structure or design of component is expected to perform certain specific function. The component have certain design life if component will failed before its design life due to this chances of occurring service failure this can tragic and expensive. Therefore care and attention are required for a component. Residual life assessment is the way to know component present condition and also knowing how long the component can work properly at certain condition, so it avoids pre mature failure and also saving cost. This paper gives basic description of residual life assessment.**

Keywords- residual, component, life

I. INTRODUCTION

The engineering components are designed for a specified period. Premature failure does take place for a variety of reasons viz., design deficiencies (lack of knowledge), material selection deficiencies, processing deficiencies, assembly and installation error, operational and maintenance error, and environmental impact. In addition one must realise that every design has a probability of failure. This is because both the material property and the loading condition. There would always be chances to increase loading above the critical value or the material used may have inferior property. However, depending on the level of factor of safety used, the probability of failure is always very low (10-6 /10'7), but it increases with prolonged service. Old components are likely to be more chances to failure primarily due to the natural process of ageing and also due to the fact that so far no failure has taken place; a characteristic of any stochastic process. There are several natural processes of ageing of structural materials e.g. corrosion, fatigue, wear, creep, shock loading etc. Microstructural damages keep on accumulating in the component due to any one or a combination of the above factors. As a result its load bearing capacity continues to decrease. Failure takes place when it falls below a critical level determined by the component geometry and loading.[1] 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. Specially this will be widely used in power plant for assessing residual life of high temperature component. 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.[2]

II. NEED FOR RESIDUAL LIFE ASSESSMENT

Life assessments are needed to avoid unexpected component failure and premature replacement of components prior to the end of useful life. One important factor affecting the life consumption of high temperature components is the nature of the stresses generated by the applied mechanical and thermal loads. For design and analysis, stresses are classified as either load controlled or displacement controlled. The hoop stress in a pipe produced by internal pressure is an example of a load controlled stress. The axial stress in a bolt produced by an initial applied stretch is an example of displacement controlled stress. Displacement controlled stresses are repeated or cyclic and relax with time. Because of the accumulation of creep damage with continued cycling, displacement controlled stresses can lead to failure. Because of the high cost of component, it is clear that replacements should be performed only when the component is near the end of life. [3]

It is clear that residual life assessment is essential to avoid unnecessary failure of component. It directly affect the cost and time.

III. METHODOLOGY OF RESIDUAL LIFE ASSESSMENT OF ENGINEERING COMPONENT

a) Collection of back ground information

Plant data management plays an important role and involves the collection, storage, and manipulation of data associated with operating and maintenance histories, inspection, failure analysis, life assessment, resources, schedules etc.

b) Material Data

Following information are required to be collected regarding the set whose life is to be estimated:

-The drawings of critical components viz. rotors, casings, valves & valve chests, guide blade carriers, steam inlet & exhaust connections etc.

-Materials of various critical components as mentioned above & their test certificates including NDT results like defectograms etc.

-Thermodynamic cycle and strength design data. Stress distribution in various critical components as envisaged during design stage.[5]

c) Operational History

It is very important to know how the set has been operated in the past at the power station or industry. The effectiveness of the calculations made depends upon the accuracy of this data. The observations during planned shut downs provide lot of information on equipment's condition. Generally, the Maintenance Planning Division of the power plant or industry utilises this information for preventive maintenance and replacements. History cards covering the replacements done during routine maintenance / forced outages and planned overhauls are reviewed so that present status of the component is assessed and component degradation trend is formulated.[5]

IV. TESTING PROCESS INVOLVED

Ultrasonic Testing (UT)

By using high frequency sound waves, the surface and sub-surface flaws can be detected. Cracks, laminations, shrinkages, cavities, flakes, pores and binding faults that act as discontinuities in metal gas interfaces can also be easily detected. This technique also used for measuring oxide scale thickness of high temperature tubes.[4] see illustration n figure.1.

[4]

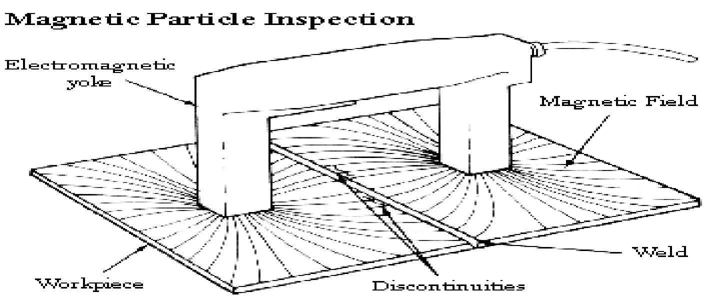
Fig.1

Visual Examination (VE)

During visual inspection the observations made with reference to discoloration of coils, misalignment is considered in deciding sample tubes removal for metallurgical examination. Prior evaluation of pressure part condition, based on experience and design knowledge from similar plants makes sample selection more rational. Visual examination is carried out to assess material wastage due to oxidation, erosion/corrosion problems, fouling conditions of heat transfer surfaces, integrity of attachments in coils. This includes inspection of drum internals to ensure proper steam/water separation.. Samples from the regions thus determined to be most susceptible to failures and samples depicting the general condition of each component are selected for an evaluation of the metallurgical condition.[6]

Magnetic Particle Inspection (MPI)

Magnetic particle inspection helps to detect cracks and discontinuities on or near the surface in ferromagnetic materials using dry magnetic particle testing equipment. The technique is adopted for locating surface and sub-surface discontinuities like seams, laps, quenching and grinding cracks and surface rupture occurring on welds. This method is also used for detecting surface fatigue cracks developed during service [7]. see illustration n figure.2.

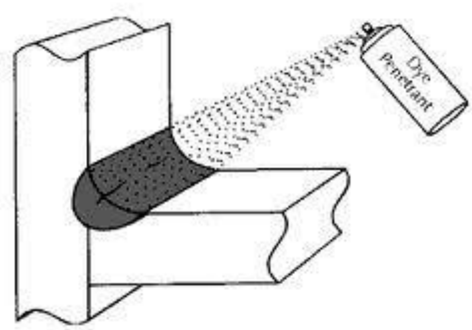


[7]

Fig.2

Dye Penetrant Inspection (DPI)

In principle the dye /liquid penetrant is applied to the surface to be examined and allowed to enter into the discontinuities. All excess penetrant is then removed, surface dried and the developer applied. The developer serves both as a blotter to absorb the penetrant coming out by capillary action and as contrasting background to enhance the visibility of the indication. Method is adopted primarily for detection of cracks or crack like discontinuities that are open to the surface of a part, like surface porosity, pitting, pin holes and other weld defects.[5] see illustration n figure.3.



[5]

Fig.3

Replication (R) [In-situ Metallography]

The process involves preliminary preparation of the metal surface using polishing equipment. When the spot is ensured free from rust and polishing will be done using abrasive paper of varying grits from 120, 200, 400 and 600 in sequence. Subsequently diamond paste lapping is done followed by etching with 3% inital to reveal the structure.[6]

Adopting Electro-polishing can also do the surface preparation. After the preparation of the surface the microstructure of component is truly transferred to a film. Transparent film with green reflecting foil can be used which can be examined in laboratory with magnification up to 500X to assess the metallurgical damages like creep cavitation.[4]

Hardness Measurement (HM)

A portable hardness tester is used for in-situ hardness measurement of various critical components like steam drum, high and low temperature headers, pipelines etc. Hardness measurement aids in assessment of metallurgical status/ condition of the component.[4] see illustration n figure.4.

[4]

Fig.4

From above all testing process gives us material present condition and we get various observation about component that will helpful in assessment of remaining life.

V. METHODS OF ASSESSMENT OF RESIDUAL LIFE

A}Oxide scale thickness method

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:

$$\mathbf{Log\ X = 0.00022\ P - 7.25}$$

$$\mathbf{P = T\ (\ 20 + \log t\ )}$$

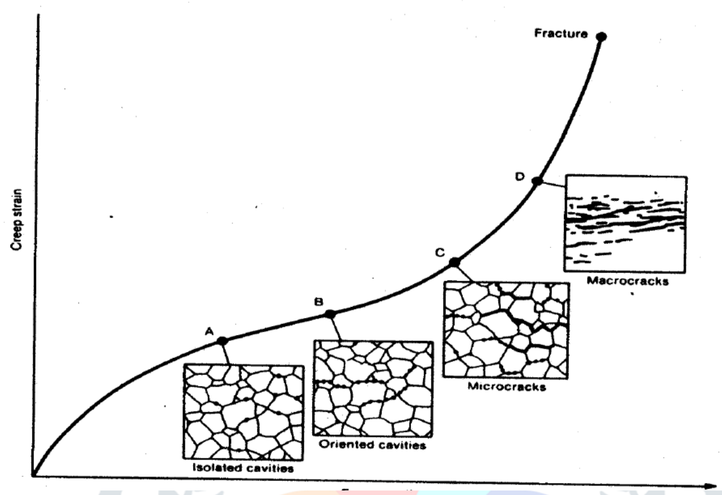
where, X – Scale thickness in mils

P – T (20 + log t)

T – temperature in 0 R (0 F + 460)
t- time in hours.

B}Metallographic analysis method

In high pressure and high temperature components, 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 due to the status of the component in terms of its remaining life. The conclusions drawn, however, are not deterministic. Nevertheless, the component susceptible to consequent failures could be identified and necessary action(s) could be initiated. 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).



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Expose time
Graph.1

Fatigue Usage Fraction

Using the maximum stress due to thermal and pressure load during the transient as the alternating stress range (S range), with the lower limit being zero 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.[9]

Creep Usage Fraction

Using the maximum stress due to thermal and pressure load in the steady state operating condition, creep life usage fraction (Uc) is obtained from creep curve (S – T curve) of the material at the operating temperature.[9]

Residual Life Assessment

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 of component is normally taken as

RLF = (½) – Uf – Uc. [9]

Estimation of Fatigue Damage

Fatigue damage is required to assess residual fatigue life. For this purpose S-N curves for the girder steel are required. The fatigue damage is then computed using Palmgren Miner's Hypothesis.

Palmgren-Miner Hypothesis

This hypothesis is used to assess the accumulated fatigue damage. It states that if 'Ni' cycles of a constant amplitude stress range (Sr) cause failure, than 'ni' cycles of 'Sr' will use up a fraction 'ni/Ni' of the life. Failure will occur when the sum of used life fractions i.e. Damage sum (Df) will reach unity, i.e.,

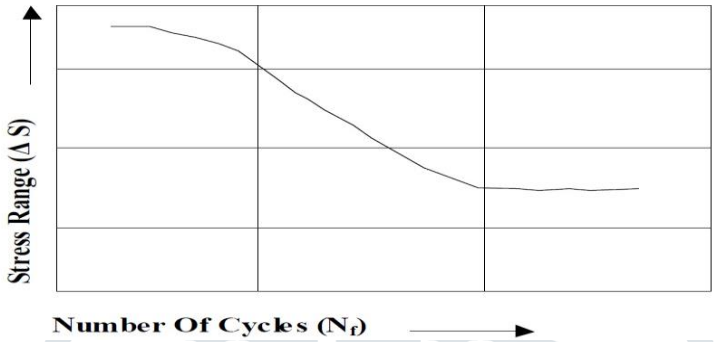
Df = ∑ ni/Ni = 1.0

Where,
ni=number of stress cycles actually applied

Ni= number of stress cycles to failure (To be taken from S-N curve)

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. The S-N curve shows the number of cycles, Nf, 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 Nf. But beyond this, the details of the curves depend on several physical factors and may be given different mathematical representations.[2]



[2]

Graph.2

VI. CONCLUSION

In this paper, we general ideas about residual life assessment. And we studied various techniques of finding present condition of material. Most popular technique is non destructive technique. Which are widely used in industries. A broad overview of two distinct approaches for remaining life assessment of engineering components has been presented. A complete life assessment exercise on any equipment is no doubt going to be expensive and time taking. Therefore, for convenience the entire exercise is divided into different levels.

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