A RLA BASED MAINTENANCE STRATEGY TO EXTEND LIFE OF EQUIPMENTS AND PLANTS

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ABSTRACT

Remnant Life Assessment (RLA) of equipment/plant is the quantitative evaluation of the interaction of all the operating loads resulting into corresponding stresses/strains and the material defects/degradation under the operating environment. This evaluation results into assessment of the remaining life of the component under given operating conditions and material integrity and also identifies the components to be repaired/replaced for uninterrupted rated output of the equipment/plant. It also evaluates the recommendation for further operating the equipment in case the repair/replacement recommendation can not be implemented immediately on account of certain constraints. This capacity of RLA study can be very fruitfully utilised in appropriate planning of maintenance schedule and programme instead of carrying out ritualistic preventive maintenance overhauls. By identifying critical components for repair/replacement, one can also assure extended life to the equipment/plant for a reliable, uninterrupted and rated performance. A few case studies are presented here.

KEY WORDS

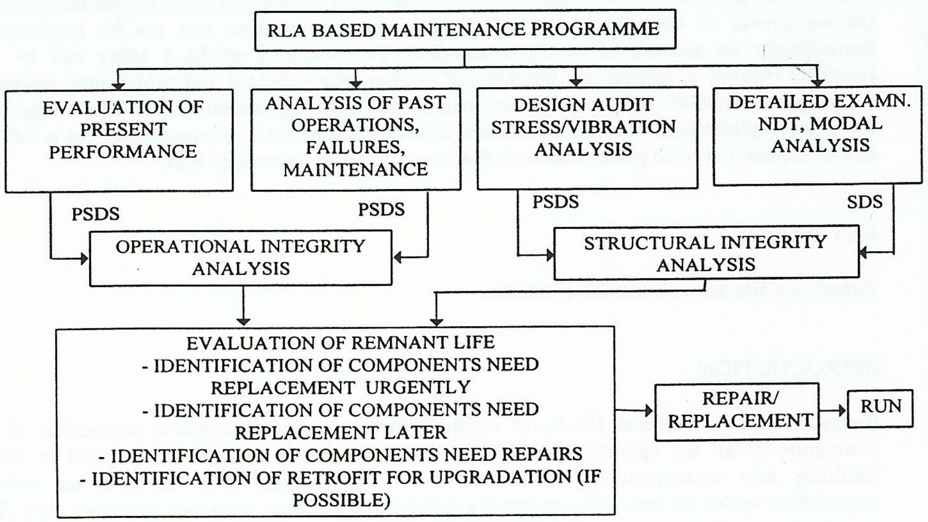
Remaining life assessment, life extension.

INTRODUCTION

Remnant Life Assessment (RLA) of equipment/plant is the quantitative evaluation of the interaction of all the operating loads which could be steady as well as transient in nature resulting into corresponding stresses/strains (static/dynamic) and the material defects/ degradation under the operating environment (high temperature, abrasive, corrosive etc.). This quantitative evaluation results into assessment of the remnant life of equipment under given operating conditions and material integrity. This assessment also helps in identifying the components of the equipment/plant to be repaired/replaced and their timing. In case the aforesaid repairs/replacements cannot be done by stipulated time, the study also helps in arriving at modified recommendations regarding operating procedures, derating etc. In view of this, RLA study carried out during planned maintenance could guide the operation regarding the next overhaul maintenance schedules and actions to be taken. As would be explained later, the RLA studies are mostly non-invasive in character in a sense that all the activities pertaining to such studies can be executed during the planned duration of the overhaul and no extra time would be required. The machine then can return to its operating condition.

The techno-economic necessity to extend the life of component/plant equipments in different type of plants built 20 - 30 years before is as significant to the developing countries as it is to the developed countries. Additionally for developing countries like India, where installed capacity is too inadequate to meet the demand, it is absolutely necessary to ensure highest reliability/availability and plant load factor for which appropriate maintenance strategies need to be formulated. The cost of untimely and unnecessary maintenance are finally borne by the society in addition to loss of productivity. From this point of view, RLA based maintenance strategy appears to be best especially for developing country like India.

As mentioned earlier, life assessment aims at finding suitability of the component for further service under given operating conditions. This is best judged by ascertaining (a) the operational integrity of the equipment prior to shut down and (b) structural integrity of the components during shut down. This coupled with analysis data of past operations/failures/problems encountered and strength calculation for the given structural integrity of the component, gives an idea of the remnant life, repairs and replacements to be undertaken and their timing etc. This is described by Fig. 1.



Note : PSDS - Pre-sutdown survey, SDS - Shut down survey

Fig. 1 SALIENT FEATURES OF RLA BASED MAINTENANCE PROGRAMME

In other words, the life assessment studies carried out during the overhaul do help in appropriate timing of the next overhaul, thereby eliminating costly ritualistic overhauls normally undertaken due to lack of proper knowledge about the condition of the plant in previous overhaul.

METHODOLOGY

(A) Structural Integrity

Each major component has a finite original design life based on an expected load history, earlier calculation methods and material data. Approaching the end of design life does not necessarily mean that the component has to be taken out of service but it means that a so called warning point has reached and that it is necessary to evaluate the actual condition or structural integrity based on the load history, damage accumulation etc. A remaining life evaluation based on latest knowledge results in a new effective warning point which includes the expended life based on the actual/past operating conditions and the expected future loading conditions. The difference between the recalculated effective warning point and the expended life gives remaining life of the component for the specific operating conditions.

An essential step in developing remnant life assessment procedures is to establish a methodology that considers the type of component, the materials of construction, the operating regimes, the material degradation and failure mechanism, the failure history, lead times for repair/ replacement and the costs of refurbishment. This concept relies upon determining the present degree of damage in the component, the rate of damage accumulation and the degree of damage required to cause failure. Depending upon the operating regime and actual environmental condition damage can be brought about by creep, fatigue, corrosion etc., acting alone or in combination. This implies that if an estimate of the current damage, along with a rule for damage accumulation and a failure criterion of a component are known, then its present structural integrity and remaining life can be assessed. For this purpose a detailed Non-destructive examination (NDE) of the component is carried out and the stress/vibration behaviour of the component with the defects as detected in NDE/Modal analysis and microstructural examination are evaluated. Once these information are known one can use damage accumulation rules and also fracture mechanics analysis.

(B) Operational Integrity

The basic pattern with regard to failure rate as a function of operational hours is a 'bath tub' curve as shown in Fig. 2. Under normal operating conditions, after an initial period of teething troubles, the reliability of the units remain fairly constant say upto about X years. The failure rate thereafter increases rapidly as a result of accumulated time dependent material degradation. Continued operation beyond this point results in much faster deterioration in performance of the plant. By carrying out performance monitoring of the equipment prior to shut down and critical analysis of past operational data, one can get excellent idea about operational integrity.

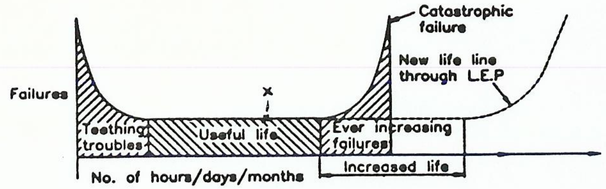


Fig. 2 BATH TUB CURVE

3- Level approach for assessment

Depending upon the age of the equipment/plant and analysis of past operational data, one can consider the life assessment by 3-level approach. This approach is described briefly in following lines and case studies are cited to highlight the approach.

Level - 1: This is generally used for 'younger' plants with seemingly no chronicality of particular problem. For such cases, only design or overall service/design parameters need to be examined to ascertain on the basis of most conservative consideration. This involves two steps. In first step design parameters, design stresses, thermal and mechanical properties etc. are checked. In second step, check is done on excess of design parameters during operations, future operation involving temperature, pressure, cyclic loads, etc. The operating integrity of the equipment however needs to be ascertained.

Level - 2 : This is generally recommended for machines 'not so young' and where availability is on decrease. It requires that information should be generated through an initial inspection, "simple" stress analysis, measured dimensions or operating parameters etc. If the residual life determined here is less than the projected/expected extended life, then only Level -3 should be approached.

Level - 3 : This is generally recommended for 'old' machines where problems are also on rise. New machines maloperated also come under this category. In this level, a very `refined' and `detailed' stress analysis is essential. Also material properties should be measured. All these represent increase in cost and execution time as the level of assessment increases.

Generally, it is observed that for the components whose life is to be assessed are old as mentioned earlier and may be operational for 20-30 years, operational data may not always be available and in such cases Level - 3 assessment is inevitable.

CASE STUDIES

(1) Rotor Life Evaluation : Fig. 3 gives the flow chart for evaluating the remaining life of rotor. The data required for this are operational history and parameters. Detailed NDT are done on regions prone to cracking. In-situ microstructural examination gives the idea of metallurgical conditions and creep damage because of the high temperature working environment. The detailed stress/strain analysis based on design and operating condition are necessary to ensure

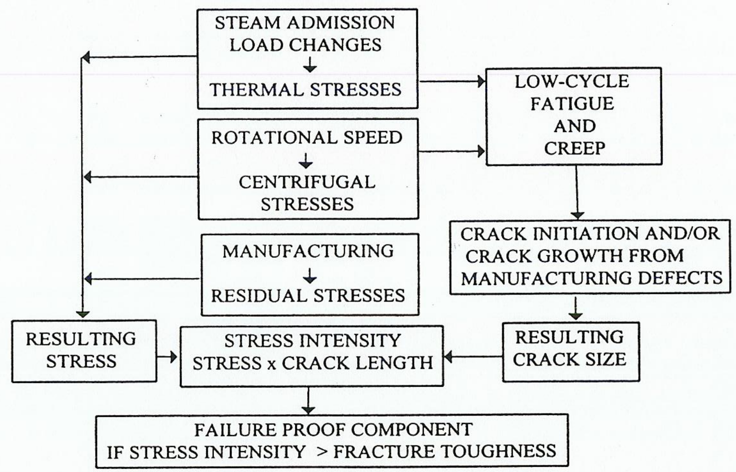


Fig. 3 STEPS INVOLVED IN ROTOR LIFE EVALUATION

safe operation under creep and low cycle fatigue (LCF) conditions and also without brittle fracture. Non-steady state operating conditions expose the rotor to LCF and large rapidly changing conditions can lead to plastic strain in component sections with high stress concentration level. At grooves, slots or transition zones, material damage is caused by LCF cracking whereas creep result in a strain consumption less than 1%. Life expectancy can be improved by improved contouring to reduce the stress concentration factor as has been done for this case as shown in Fig. 4 (Chowdary and Bhave, 1989).

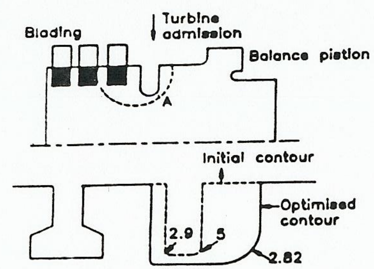


Fig. 4 STRESS CONCENTRATION IN HEAT RELIEF-GROOVES

(2) Life assessment of 82.5 MW Turbine : Life assessment has been carried out on a Turbine by Universal slope method (USM) and LCF data (Bhave, 1990). In USM it is common to predict the number of cycles to failure for a given total strain range. In the absence of strain range, these were evaluated based on the available von Mises stress values. Fig. 5 shows the evaluation curves based on 10% rule USM for thermal stresses. The number of cycles to failure can be obtained from 10% curve (Fig. 5) after knowing the % total strain range. Alternatively

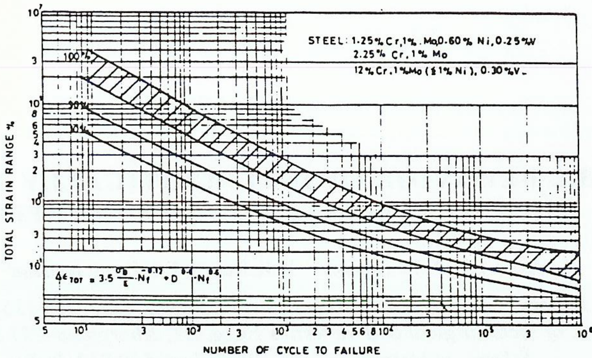


Fig. 5 MINIMUM VALUE DESIGN CURVES ACCORDING TO USM AND 10% RULES *(Bhave, 1990)*

with the LCF data also the number of cycles to failure can be obtained. Using LCF curves, the number of cycles to crack initiation can be determined for a given total strain range. Fig. 6 shows this for some power plant materials.

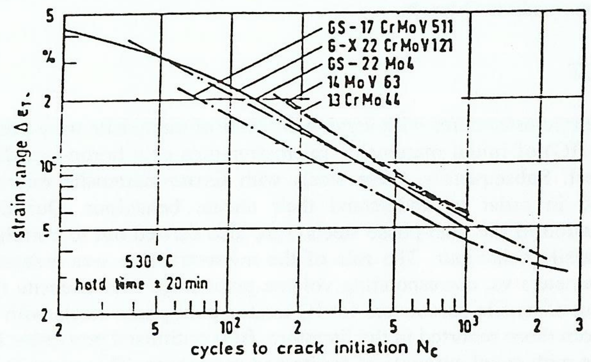


Fig. 6 LCF DATA ON SOME POWER PLANT MATERIALS *(Bhave, 1990)*

(3) Assessment based on 3-Level approach for turbine (Bhave et al, 1994) :

(a) Based on Level-2 approach, during a routine natural frequency test on LP rotor of 60 MW turbine indicated significantly different natural frequencies on a LP disc. This observation led to a detailed probing by ultrasonic method which revealed a 75 mm deep crack originating from its keyway of the disc which shrunk on the rotor (Fig. 7). The fracture mechanics analysis of the cracked disc showed a very insignificant amount of time for the crack to reach its critical size. The disc was replaced with a new one.

(b) On the basis of Level-2 approach, in a 200 MW turbine-generator unit, very high vibrations were noticed. The detailed vibration survey showed spiky nature of vibration on generator bearings and spectrum analysis also confirmed unhealthy status of rotating parts. Fig. 8 shows this. The Bode plot, Fig. 9, during the run down of the machine showed critical speeds much differing from the design critical speeds. The unit was shut down immediately for

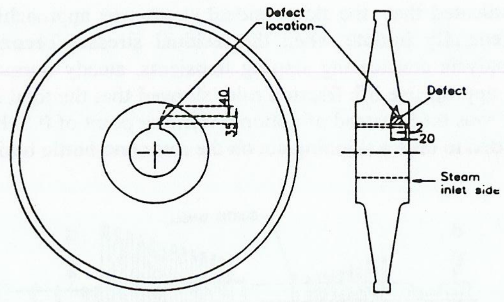


Fig. 7 CRACK EMANATING FROM KEYWAY*(Bhave et al. 1994)*

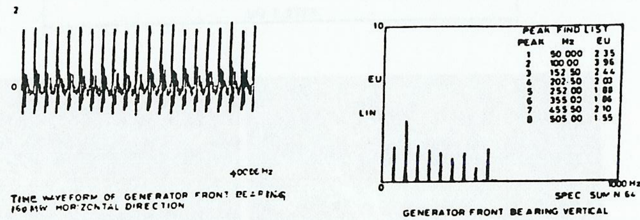


Fig. 8 VIBRATION TIME WAVE FORM AND SPECTRUM *(Bhave et al. 1994)*

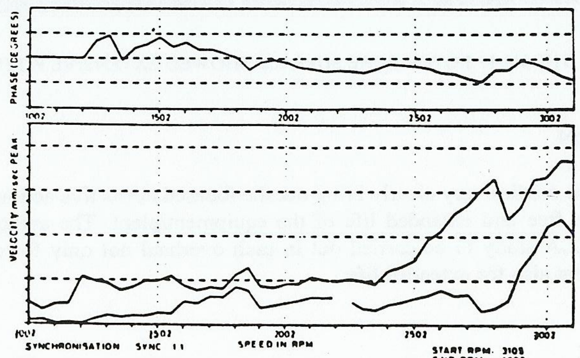
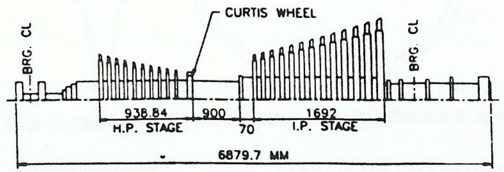


Fig. 9 BODE PLOT*(Bhave et al. 1994)*

inspection of rotating parts. These analysis and inspection showed that while turbine components were in a very healthy condition, the turbine side end retaining ring nut had cracked by 70% circumferentially. The origin of the crack was from the corner of the slot where nut tightening device is placed. Replacement of the end ring nut, regrouting of the seating plate and resetting of the bearing and shaft catenary, brought the system to its peak performance.

(c) Level-3 approach was used for 150 MW GE turbine, in which neither normal NDT did reveal any significant defects nor microstructural examination revealed significant degradation. The HP-IP rotor bore surface however showed extensive pitting (Fig. 10) and residual stress measurements indicated that the skin residual stress was approaching the tensile value. The fatigue cracks generally initiate when the residual stresses become tensile in nature. The detailed stress analysis considering starting transients, steady normal operating conditions in conjunction with appropriate life fraction rules showed that the total expended life fraction due to creep and LCF was 0.65 instead of notional warning point of 0.5. Based upon these findings, it was recommended to take a skinning cut on the rotor and bottle boring of the rotor bore.



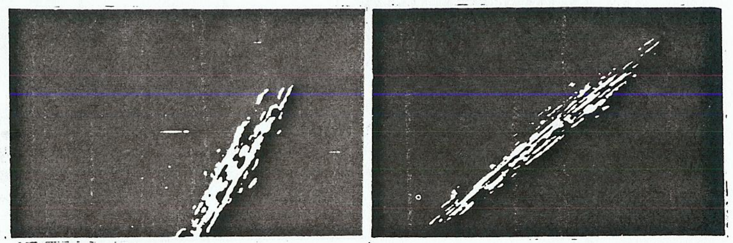


Fig. 10 THE HP-IP ROTOR BORE SURFACE SHOWED EXTENSIVE PITTING (*Bhave et al. 1994)*

CONCLUSION

The above case studies very clearly bring out the focused corrective actions to be undertaken to ensure trouble free and extended life of the equipment/plant. The authors therefore strongly recommend RLA study to be carried out in each overhaul not only for avoiding unnecessary maintenance but also for extended life.

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