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FUNDAMENTALS OF CONDITION ASSESSMENT

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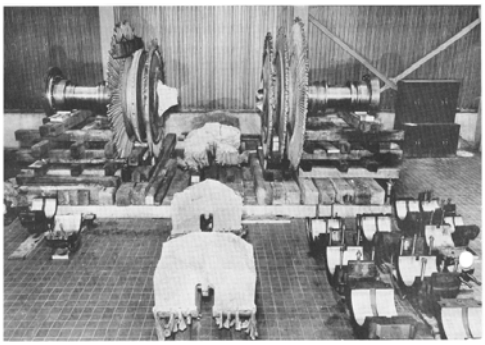
Condition assessment for turbomachinery, in general, can be defined as determining the condition of an in-service component based on its inspection data, metallurgical data, stress levels and operating conditions (operating hours, duty cycles, environment etc). Probabilistic crack initiation and/or crack propagation analyses are performed to determine the remaining life of the component. And thus based on the analyses, a safe, risk-based inspection interval can be recommended for the subsequent service life of the component.



Condition assessment is critical. Catastrophic failures have occurred in the past history due to operating conditions and/or poor metallurgical properties over the service life of the component as shown in the figure to the right.

Determining stress fields …applying fatigue and fracture mechanics …probabilities of failure, etc.

As an example, a LP rotor with a bore has highest circumferential (hoop) stress at the bore surface under the last stage of the rotor. The stress field varies along the axial length and radial direction of the rotor. The stress is maximum at the overspeed and minimum at standstill. A crack can occur due to fatigue and can grow to cause a catastrophic failure if left uninspected. An NDE inspection can predict the size and orientation of a crack. And, if crack-like indications are found, over boring is an option to remove the indications.

A probabilistic fracture mechanics analysis can be performed to determine the severity of the crack which is defined in terms of stress intensity factor (KI). The stress intensity factor is the function of the original stress field at the crack location, crack size & shape, and ligament width. The KI value is compared to material inherent property called fracture toughness (KIc) to determine failure probability. Theoretically, stable crack growth is expected until KI equals KIc when overload failure occurs. Due to statistical variation, a distribution on mean value of various parameters is used. A Monte Carlo simulation technique is used which defines failure probability as the ratio of number of times KI is equal to or greater than KIc, by the total number of simulations. This failure probability would increase with the crack growth. Hence, an inspection interval is determined as per safe failure probability for an additional number of years of operation.

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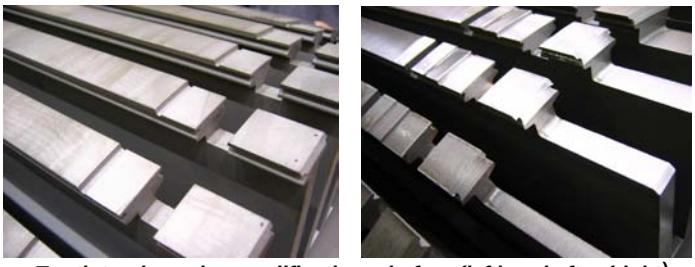
Components and conditions where assessments are typically performed.

Condition assessment is performed on various rotating and stationary components, such as turbine/generator rotors, generator rotor retaining rings, dovetails and tooth tops, turbine rotor blade attachment areas and shrunk on disks, casings, inlet sleeves, etc. This technique can be applied to any other turbine-generator component.

In the case of generator rotor tooth top modifications, fatigue life before the modification was about 500 start/stops. Fatigue life after the modification improved to more than 10,000 start/stops.



Tooth top long ring modifications, before (left) and after (right)

Typical outcomes of the condition assessment analysis are run as-is, run with repair and replace type of recommendations. An inspection interval is recommended in terms of maximum additional operating hours and duty cycles (start-stop, overspeed cycles etc). Modifications in operating conditions, design and other remedial solutions can be recommended.

Remaining life of a component is evaluated when a crack is allowed to grow until it reaches it critical crack size or maximum tolerable crack size as per material toughness. At this point an overload failure occurs. However, for safe operation of the component, an inspection interval is recommended which is based on low failure probability and therefore is typically shorter than remaining life of the component.

However, for some components, crack initiation is conservatively considered as a failure point and therefore, remaining life is defined as time to initiate a crack in a component.