STEAM TURBINE ROTOR BORE FRACTURE EVALUATION

Introduction

Performing a stress analysis and fracture mechanics evaluation of a turbine rotor bore can extend the life of the turbine rotor or increase the turbine rotor bore inspection period. Typical recommended inspection periods from the original equipment manufacturer may vary from seven to ten years and are based on the condition of a fleet of turbine rotors rather than an individual rotor.

A stress analysis and fracture mechanics evaluation of a specific rotor can produce inspection periods of ten to fifteen years delaying the cost of an inspection or the replacement of a problem rotor.

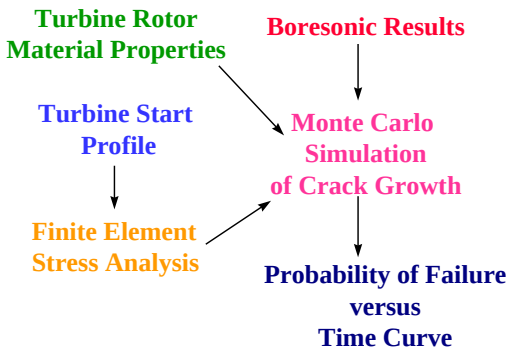
Overview

Once in service turbine rotor bores are examined ultrasonically on a periodic basis to look for any indications of cracks or other defects. Based upon the results of this examination the rotor is allowed to continue in operation, is repaired if necessary or is replaced. Often this decision is made by comparing the condition of a rotor under examination to the condition of a fleet of similar rotors rather than performing a detailed fracture mechanics analysis. A detailed evaluation will examine an individual rotor. This means that its unique material properties, start up characteristics and detected near-bore flaws are used in the evaluation.

During the normal operation of the turbine rotor any existing crack will grow in a stable manner due to thermal fatigue cycling each time the unit is started. The stable growth rate of a crack in the turbine rotor bore can be estimated from the depth and length of the crack, the nominal stress surrounding the crack and the material properties of the rotor. As the crack grows to some critical depth, the growth becomes unstable and the turbine rotor will fail.

As with any remaining life analysis, the analyst first wishes to quantify the three distributions that affect the growth rate of a suspected crack. These are the stress which drives the crack, the material's resistance to cracking (fracture toughness) and the crack depth.

The evaluation process is not a simple one but is a worthwhile endeavor over the life of the turbine rotor.



Finite Element Stress Analysis

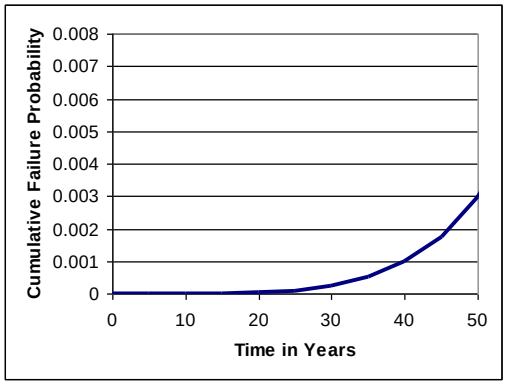
The stress which drives the crack is estimated using a computerized finite element stress analysis program which evaluates the level of stresses in the bore

due to thermal and mechanical load. Thermal stresses are caused by the uneven distribution of temperatures during a start-up.

Turbine Rotor Material Properties
Fracture toughness can be measured by Charpy impact tests in which material samples are broken at various temperatures. Yield strength and tensile strength are measured from tests on miniature samples from the rotor. If these tests were not done during the forging of the rotor, they can be performed on a ring sample cut from the coupling end of the rotor.

Boresonic Results
The results of the ultrasonic examination are a series of "hits" which are reported in terms of axial location, radial location and angular position. These "hits" are then clustered to determine if they are significant. If they are, then their dimensions are measured.

Probability of Failure vs Time
These three inputs are used in a Monte Carlo mathematical simulation of crack growth to predict crack growth in the future and the probability of failure. Monte Carlo simulation provides a way of dealing with the uncertainty in the values of the fracture toughness, stress, temperature, crack depth, etc. encountered in an evaluation. The result is a curve of failure probability versus time.



WHAT ARE THE ADVANTAGES OF TURBINE ROTOR BORE CONDITION ASSESSMENT?

1. Rotor bore reinspection intervals are increased.
2. Rotors are not replaced without a strong technical basis.
3. Problem rotors can have their life extended if operational procedures are changed

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