Structural Integrity Associates, Inc.®

TURBINE GENERATOR
MULTIDISCIPLINARY SERVICES

1-877-4SI-POWER structint.com

TURBINE & GENERATOR SERVICES

Structural Integrity Associates provides a comprehensive, fully integrated solution for assessment of turbines and generators. Our team offers an in-depth understanding of the complexities associated with turbine and generator operation and familiarity with industry issues, including known flaw locations and orientation in similar machines.

We offer unmatched inspection and life assessment services for rotors, using the most advanced tools and technique in the industry. Our services include:

- rotor bores & solid rotors
- shrunk-on disks
- blade attachment dovetails
- turbine blades
- turbine main inlet sleeves and nozzle chambers
- turbine and valve casings
- generator rotor dovetails
- retaining rings
- coupling keyways, and all other critical components

In the case of turbine failures, our metallurgical testing laboratory offers a full range of testing services for rotor, disk, and blade failure analyses.

WHY CHOOSE **STRUCTURAL INTEGRITY?**

Since 1983, we use an experienced multi-disciplinary approach servicing all aspects of the energy industry, with engineering, science and technical leadership. We stand by our innovative direction and go to market with our core values to deliver the best-in-value service and solutions to our clients.

With 37 years of experience and 200 recognized industry specialists, we are **Powered by Talent & Technology**.

1-877-4SI-POWER
1-877-474-7693

24/7

Our bore honing ensures optimal surface conditions for the inspection in minimal time.

ROTOR BORE MACHINING & SURFACE CONDITIONING

Our comprehensive menu of turbine-generator inspection services includes full rotor bore machining services, as well as:

- plug removal
- honing surface preparation
- corrective machining
- plug manufacturing
- plug re-assembly

After bore plug removal, we precisely measure bore dimensions to ensure timely manufacture of the replacement plug so it is available for immediate assembly upon completion of the inspection. Our bore honing ensures optimal surface conditions for the inspection in minimal time. We use large, heavy duty systems built to accomplish the desired result quickly, as part of comprehensive integrated offering.

SOLID ROTOR INSPECTION (NO BORE)

Our team has adapted a linear phased array ultrasonic approach to inspect rotor material, for cases where the shaft does not have a bore. The entire rotor central volume is inspected by electronically sweeping the ultrasonic beam sequentially through a series of angles as the transducer scans around the rotor OD surface. The inspection includes a wide range of angles for greater assurance of flaw detection.

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ROTOR BORE INSPECTION

Our experienced team, using our optimized toolkit for inspection systems help reduce outage and inspection time.

We thoroughly inspect the bore surface and near bore region for incipient cracking and other forging flaws using an advanced digital acquisition and signal processing system for acquiring and recording data.

Simultaneous use of a multi-channel ultrasonic and eddy current inspection techniques allow us to directly compare surface and near-surface flaws. When evaluated on the EPRI performance demonstration blocks, our inspection system achieved 100% detection for all flaws, from near and far surface blocks (**reference EPRI Report 1001435**).

ROTOR BLADE ATTACHMENT INSPECTION

Our **EPRI-demonstrated process** uses data acquisition, analysis and linear phased array technology to detect and size crack in blade attachments — for both tangential and axial entry blades. By trending crack growth and performing a fracture mechanics analysis, we help owners successfully manage the run/repair/replacement decision process concerning these rotors.

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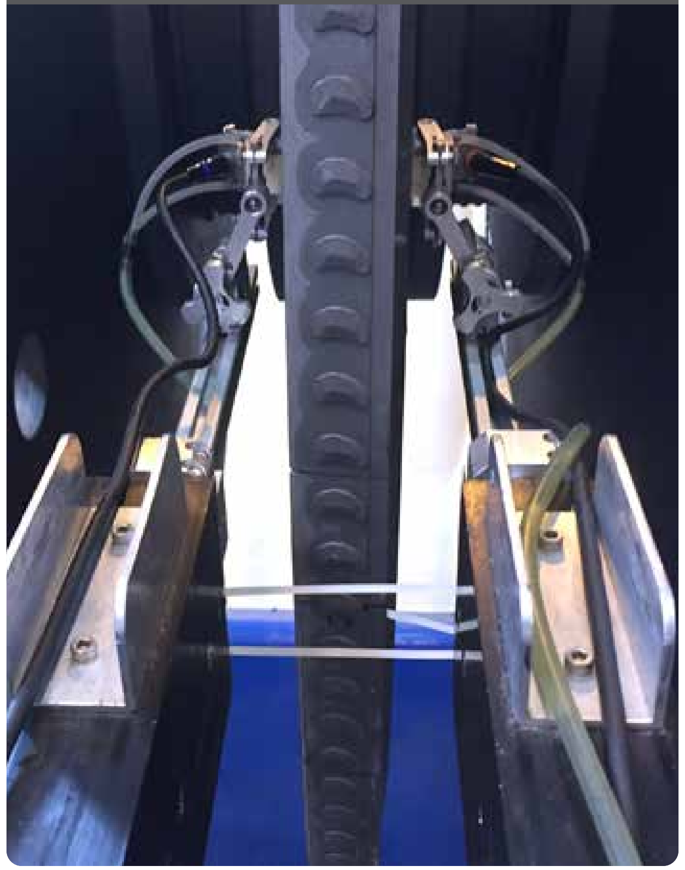
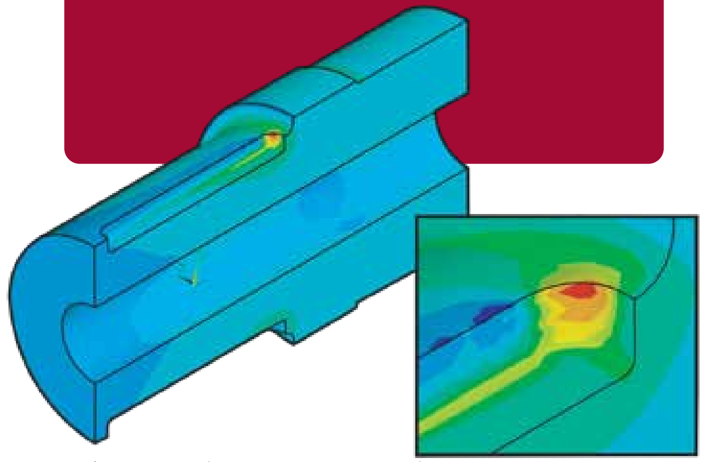


Our system allows field inspections to be performed during scheduled, forced outages on short notice, even when a unit is off-line only for a brief period.



GENERATOR SHAFT KEYWAY CRACKING

In response to an industry need, **our experts developed inspection, evaluation and monitoring tools to address generator shaft keyway cracking**:

- Our system allows field inspections to be performed during scheduled, forced outages on short notice, even when a unit is off-line only for a brief period. Using our advanced phased array ultrasonic inspection provides detection of generator shaft keyway cracking from the outside surface of the generator shaft — without the need for coupling removal.
- Our **Transient Torsional Vibration Monitoring System (TTVMS)** measures and records transient torsional events based on data from speed probes, allowing long-term trending, to help assess remaining fatigue life and optimizing operation conditions to avoid torsional cracking.
- Performing stress and fracture mechanics analyses determines critical crack size and crack propagation as a function of torsional excursion events encountered during future operation.

WESTINGHOUSE HP TURBINE INLET SLEEVE & NOZZLE CHAMBER INSPECTION

In response to **Westinghouse's Operation and Maintenance Memos 13 & 14 (OMM-13/OMM-14)**, we offer linear phased array ultrasonic inspection (UT) techniques to identify, evaluate and size cracking in inlet sleeves and nozzle chambers. The linear array UT inspection allows a thorough interrogation of both weld fusion lines as well as the weld root.

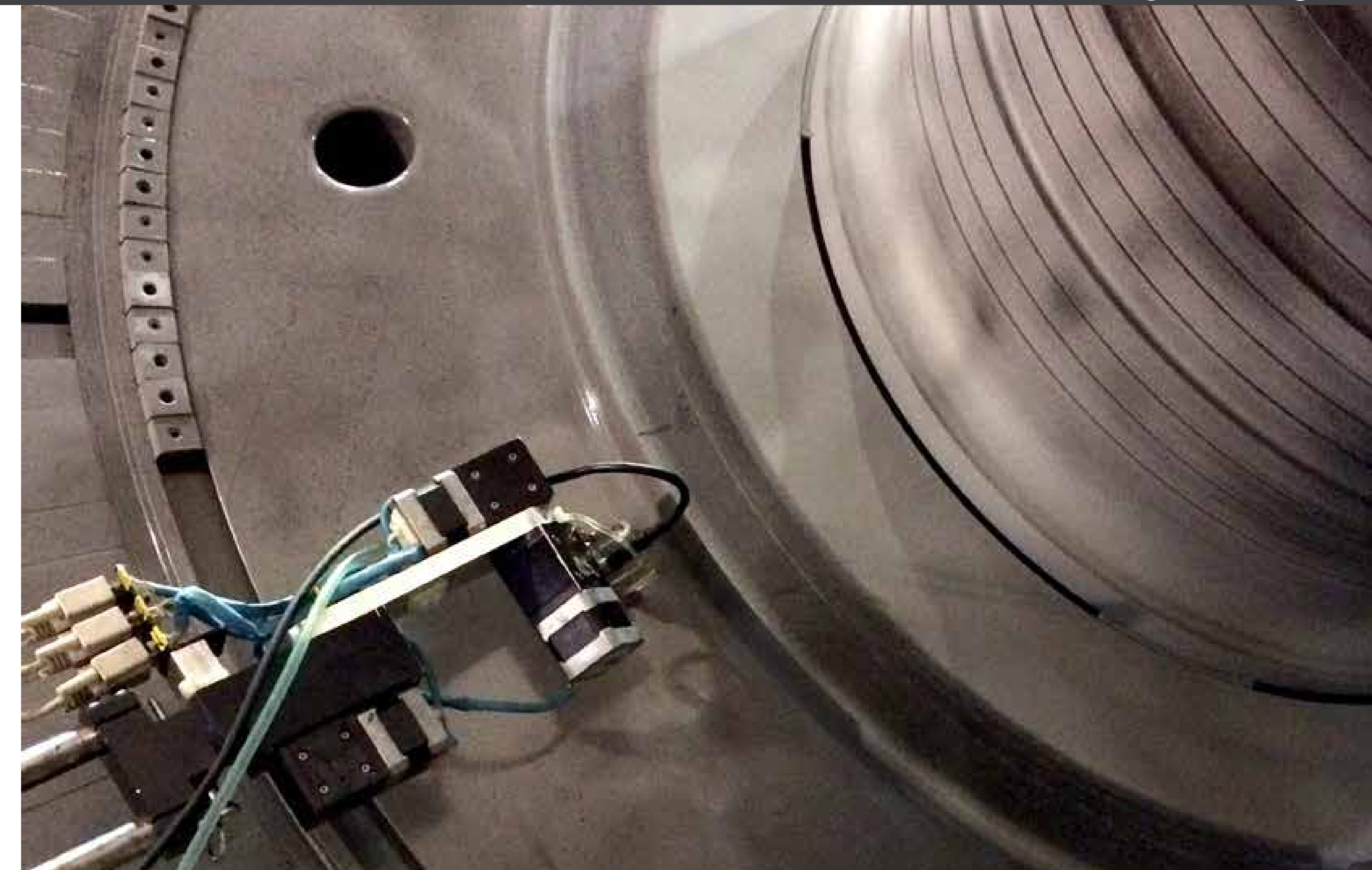
OMM-13 recommends inspection of Westinghouse HP turbine inlet sleeves on **building block type 22/222, 41, 43, 44 and 46** to identify fatigue cracking caused from flow excited vibration of the sleeves in the trepan radius. Cracks initiate at the trepan radius and propagate radially towards the sleeve bore. Due to the complex geometry and limited accessibility at the crack locations, a wet fluorescent magnetic particle technique (WFMT) and video probe are used to inspect the inlet sleeves.

OMM-14 recommends inspection of the region around the weld (bell seal area) joining the nozzle chamber to the inner cylinder on **Westinghouse HP** and **HPIP turbines**. WFMT of the nozzle chamber to cylinder weld face is conducted for detection of both circumferential and transverse cracking in the machined surface of the weld. A manual PAUT examination is performed for the detection of discontinuities in the nozzle chamber to cylinder welds for fatigue cracks which are typically oriented at the weld root either in the radial or circumferential plane within the weld.

TURBINE & VALVE CASING CRACK SIZING

Our team successfully uses linear phased array (LPA) ultrasonic inspection techniques for crack depth sizing of turbine and valve casings. The LPA provides for beam steering, in addition to electronic focusing, so less scanning is required.

The coarse grain structure, porosity, shrinkage cavities, surface condition and thickness of turbine and valve casings present challenges for cracking sizing via ultrasonic inspection (UT). Skilled at navigating these limitations, our experts use the LPA to mitigate and solve the surface condition issue.

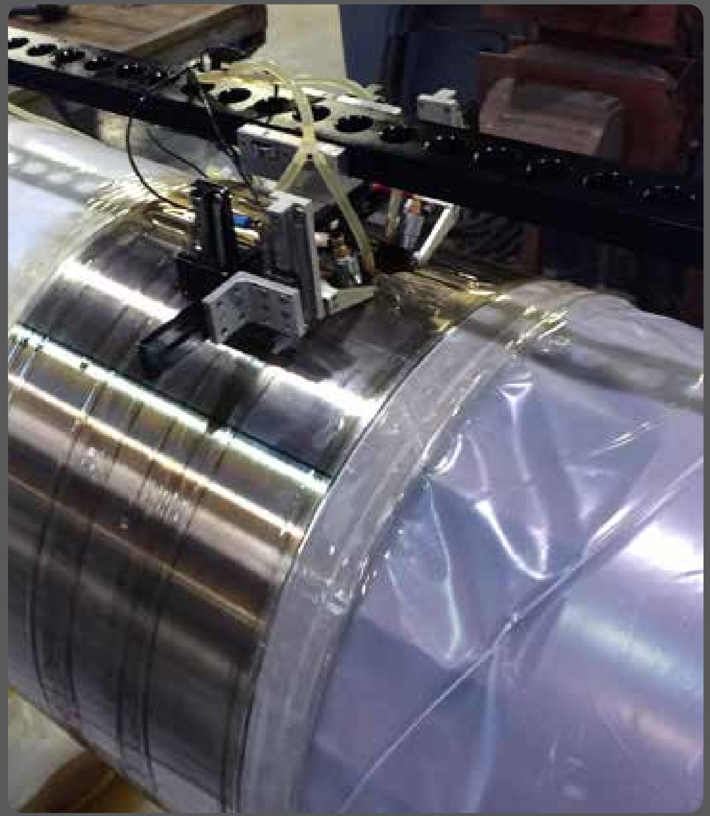


Our team successfully uses LPA ultrasonic inspection techniques for crack depth sizing of turbine and valve casings.

DISK KEYWAY/BORE INSPECTION

Our linear phased array approach provides for superior detection and sizing of cracks in disk bore/keyways, compared to the traditional use of multiple fixed-angle inspections. We offer inspection services for various keyway designs and use a specially designed scanner that eliminates the need for a special platform.

The keyway and wheel bore of shrunk-on disks are susceptible to stress corrosion cracking (SCC) due to high stresses from the shrink fit and poor cycle chemistry. Catastrophic failure of a disk could occur if disk bore/keyway cracks propagate to a critical size. Through accurate crack sizing and fracture mechanics analysis, we deliver the answers owners need to make informed decisions concerning these rotors.



GENERATOR ROTOR RETAINING RING INSPECTION

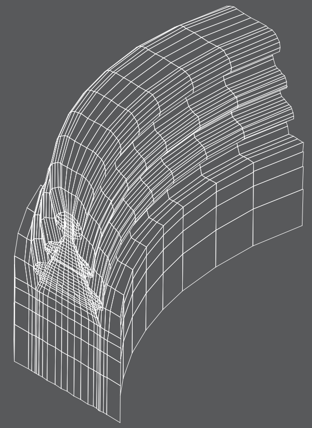
Generator rotor retaining rings require periodic inspection for assessment of continued operability. Our inspection approaches are unmatched in the industry, providing extremely high reliability for detecting and sizing even the smallest damaged forms. Our experts conduct inspections with the rings assembled to the rotors to minimize costs associated with ring removal, and to take advantage of the enhanced flaw detection afforded by the tensile hoop stresses, of the installed ring. Ultrasonic inspection of the retaining ring is accomplished by scanning from the outside ring surface for interrogation of the ring volume and the critical interference fit areas of the inner ring surface. Multi-channel pulse-echo shear wave probes are used for detection of service-related discontinuities within the retaining ring volume.

We use an eddy current (ET) technique performed simultaneously with one of the ultrasonic scans for inspection of the outer surface of the retaining ring. Eddy current is also used for inspections of retaining rings removed from the rotor. A free-standing ring has significant compressive residual stress and shifts from highly tensile when on the rotor to highly compressive when removed. Eddy current inspection does not suffer appreciable loss of sensitivity due to crack closure, therefore the preferred technique for the inspection of the OD and ID surfaces of free-standing rings.

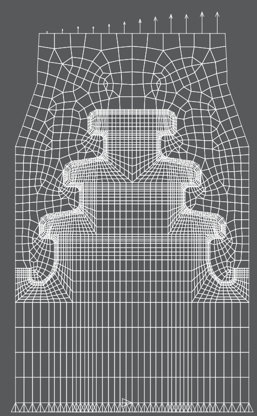
Time of Flight Diffraction (TOFD), is an ultrasonic inspection technique proven extremely useful for distinguishing between naturally occurring geometric features and in-service damage in the critical interference fit region.

LPRimLife FOR ROTORS WITH BLADE-ATTACHMENT CRACKING

Suitable for use with all rotor designs, **LPRimLife** developed on behalf of **EPRI**, is a software code to assess the life of steam turbine rotors with blade-attachment cracking. **LPRimLife** combines the necessary stress analysis and fracture mechanics' algorithms with applicable material degradation data to estimate remaining life. This sophisticated software allows owners to rapidly make critical decisions on cracks. **LPRimLife** is the solution for the most significant problem emerging in nuclear and fossil steam turbines, stress corrosion cracking in the blade attachment region of low-pressure turbine rotors.



Axial-Entry Steeple FE Model

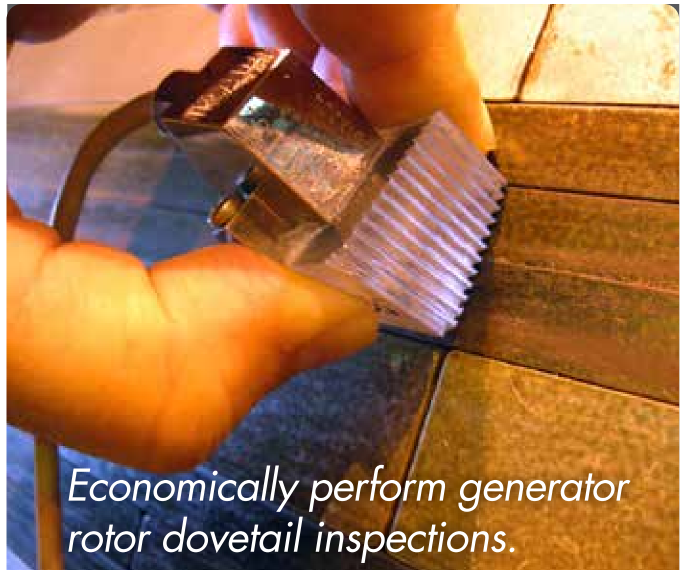


Tangential-Entry Dovetail FE Model

ROTOR FORGING LIFE ASSESSMENT

The **SAFER-PC** code was developed by our experts, in partnership with **EPRI**, for steam turbine and generator rotor applications to provide remaining life assessments of critical rotating equipment. **SAFER-PC** combines transient thermal-elastic finite element stress analysis, fracture mechanics, material property data, and boresonic data for determination of rotor re-inspection intervals, and delivers assessments, potentially saving owners millions of dollars in rotor replacement costs.

The **SAFER-PC** program helps reduce uncertainty around continued operation of older rotors. With increased cycling of units, **SAFER-PC** can be used to study the effects of operational changes on damage accumulation, enabling more accurate cost/benefit evaluations.



ECONOMICAL ROTOR DOVETAIL INSPECTION ALTERNATIVE FOR TIL 1292

In partnership with EPRI, our experts developed the state-of-the-art Linear Phased Array (LPA) UT technology to develop alternative inspection technology to economically perform generator rotor dovetail inspections. LPA UT technology effectively addresses the recommendations of **General Electric TIL 1292** without rotor disassembly. GE TIL 1292 recommended eddy current inspection of the generator rotor dovetail, requiring removal of at least one retaining ring and all of the slot wedges in the affected areas. LPA provides reliable detection and accurate sizing, even under prevailing limitations of test surface conditions.

Featuring a wide-ranging, risk-informed scope, our cost-effective, comprehensive rotor assessment package addresses 'real risks' delivering 'real benefits' specific to time, schedule impact and money/cost. Our scope of work integrates causal and fracture mechanics analyses into an inspection protocol addressing diverse damage mechanisms, including fretting and arcing damage.

GENERATOR ROTOR DOVETAIL ANALYSIS

Our proven approach to generator dovetail evaluations includes inspection (via eddy current or linear phased array ultrasonic techniques) for detection and sizing, plus stress and fracture mechanics analysis to determine the threshold crack size required for growth from high-cycle fatigue. Our analytical expertise coupled with state-of-the-art inspection capabilities allow utilities to avoid costly machining operations and extend the operating interval between inspections.

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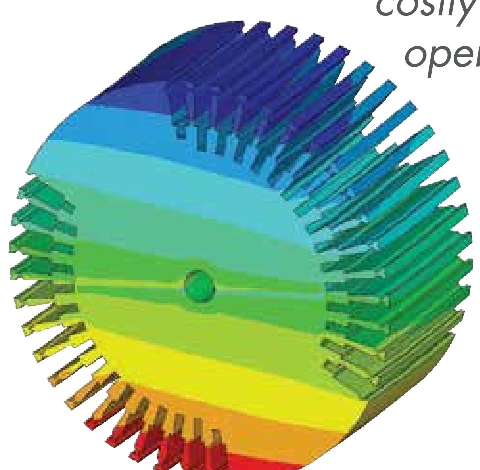
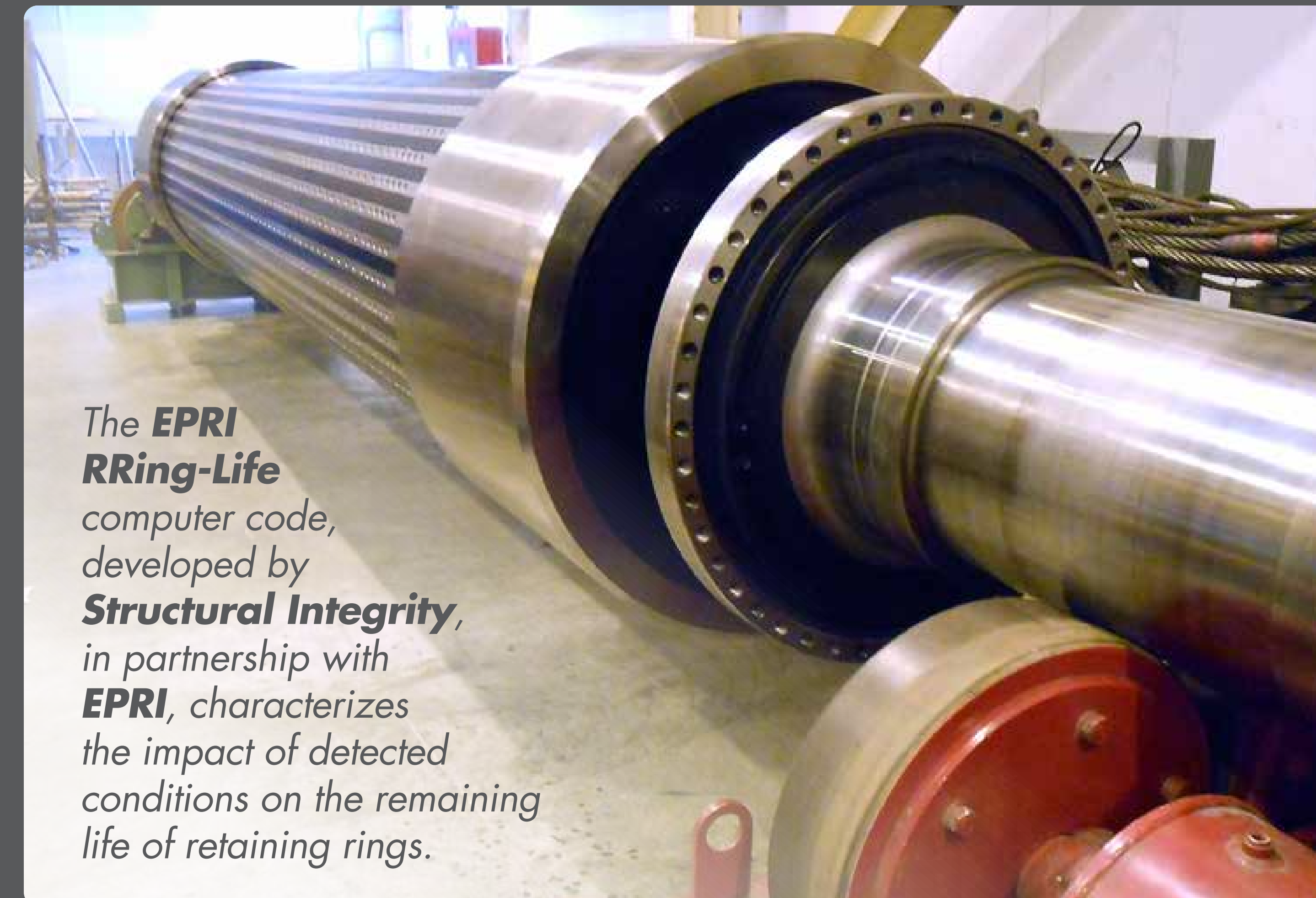

Axial Stress Contour from Bending



GENERATOR RETAINING RING LIFE ASSESSMENT

The **EPRI RRing-Life** computer code, developed by Structural Integrity, in partnership with **EPRI**, characterizes the impact of detected conditions on the remaining life of retaining rings. The **RRing-Life** program factors in geometry, stress analysis, historical operation and maintenance data, and NDE findings into the remaining life assessment. **RRing-Life** estimates the probabilities of crack initiation, crack propagation, and failure of rings based on plant-specific design and operational considerations. The resulting analysis helps owners allocate maintenance funds and mitigation activities on the most impactful areas to extend the safe operating lives of the rings.

TURBINE & GENERATOR ENGINEERING CONSULTING

Our expert engineers provide a broad range of inspection and remaining life assessment services directed specifically toward a variety of critical turbine and generator components. For unique issues, we also provide these general engineering consulting services:

- ANSYS modeling and finite element analysis of generator rotor tooth-top dovetail ultrasonic indications
- Failure and root cause analyses
- Fracture mechanics assessment in support of rotor failure analysis
- Material properties assessments
- Assessment of crack criticality
- Development of generic guidelines for turbine and valve casing inspection and life assessment **(EPRI Guide)**

TURBINE STEAM CHEST LIFE ASSESSMENT

Executing our targeted approach means disassembly can often be avoided

Our turbine steam chest life assessments begin with a finite element analysis. The analysis identifies areas requiring examination and monitoring. Executing our targeted approach means disassembly can often be avoided. In many cases, damage is monitored periodically with only the local removal of insulation. Results of the assessment are used for a complete Fitness for Service Assessment of the unit, including re-inspection interval, monitoring requirements, repair/replace options and schedules.

A specialized machining tool, extracts a small wafer from the most critical region of a rotor bore or the side of a turbine disk, leaving a smooth, harmless dimple in the surface.

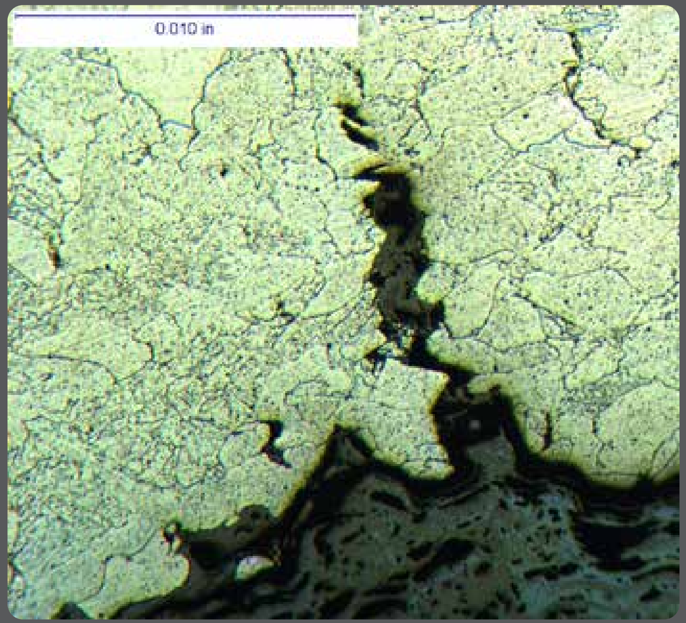
MINIATURE SAMPLING FOR ROTOR MATERIAL CHARACTERIZATION

Using a miniature sample removal allows characterization of samples from critical components, providing key information and allowing continued operation of units potentially facing recommended retirement based on database properties. A specialized machining tool, extracts a small wafer from the most critical region of a rotor bore or the side of a turbine disk, leaving a smooth, harmless dimple in the surface. These miniature samples are analyzed in our state-of-the-art lab to quantify material chemical composition, hardness, and material microstructure. This data is beneficial to determine the life extension of the component.

Remaining life assessments of critical turbine and generator components are typically based on deterministic or probabilistic analyses, using conservative (worst case) material property data extracted from public domain databases.

Our miniature sampling offer provides owner operators with real life assessment data to make future decisions, instead of relying on information from public databases.

MATERIALS SCIENCE CENTER
TACKLING
TOUGH INDUSTRY PROBLEMS RELATED TO MATERIAL PERFORMANCE



MATERIAL SCIENCE

The biggest threats to turbine-generators often have microscopic beginnings. All of our on-site investigations are backed by our state-of-the-art Materials Science Center in Austin, Texas. The Material Science Center provides an accurate picture of material condition and damage mechanisms, allowing owners to focus on the true root cause of equipment failure.

Our comprehensive metallurgical assessments characterize the existing condition of materials and measure the effects of damage mechanisms such as thermal degradation, creep, oxidation, corrosion and embrittlement to predict future performance.

Laboratory Capabilities
All of our on-site investigations are backed by our state-of-the-art Materials Science Center in Austin, Texas. Our advanced laboratory capabilities include the following – and more:

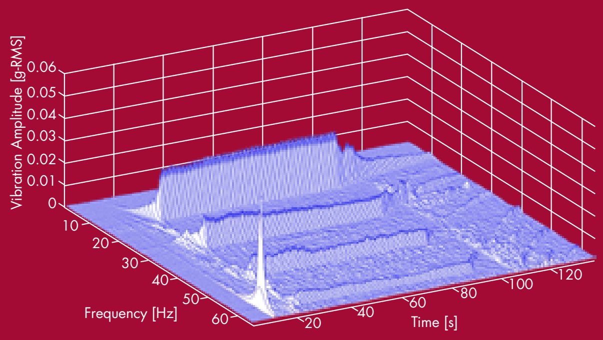
- Optical Metallography
- Quantitative Microstructural Analyses
- Fractography
- Scale and Deposit Analyses
- Metal Chemical Analysis and Alloy Verification
- Cryo-Cracking
- Heat Treating
- In-place Metallography and Replication
- Hardness Testing
- Miniature Sampling
- Specialized Corrosion Testing

VIBRATION MONITORING, TESTING & ANALYSIS

Detect emerging problems early with our vibration monitoring, testing and analysis services

Vibration monitoring is critical in power generation and analyzing turbine vibration data in greater detail during major events like startups and shutdowns is critical. Our vibration monitoring, testing and analysis services can detect emerging problems early, helping owners avoid downtime and revenue loss. Our experts dive deep into existing data and recommend additional instrumentation and diagnostics when needed.

We monitor for potential torsional fatigue damage on turbine generator shafts, by developing a **Transient Torsional Vibration Monitoring System (TTVMS)** to measure and record transient torsional events impacting shaft torsional fatigue life. **TTVMS** data can also be used to determine frequency and amplitude information of those torsional vibration modes.



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