GE Power

Rotor Life Cycle Management

For Welded Gas Turbine Rotors

Maximize rotor lifetime to meet your economic goals without compromising safety and reliability

Gas turbine rotor life cycle management

Optimizing the heart of your plant

The gas turbine and its rotor are at the very heart of the thermal power plant. GE offers you the support and continuity of a single service provider to optimize the performance and long-term value of your gas power plant. Active asset management of the gas turbine rotor and optimization of the life cycle and reliability brings you a big step closer to your long-term economic goals. That is why GE offers the Rotor Life Cycle Management program for GT8, GT9, GT11, GT13, GT24 and GT26 welded gas turbine rotors, based on rotor assessment services and OEM competence.

The purpose of our Rotor Life Cycle Management program is to detect individual component degradation early in the life cycle, in order to predict and enhance the maximum rotor lifetime while enabling safe operation beyond the minimum expected lifetime.

Periodic monitoring

Periodic monitoring and condition assessment of the individual rotor is the first step. It is performed during type C major inspections and is comprised of visual, dimensional and advanced non-destructive testing (NDT). The monitoring schedule is based on the operating regime and history of the specific rotor, addressing both creep and low cycle fatigue (LCF) driven degradation mechanisms.

OEM-based competence

Building on our OEM gas turbine rotor fleet experience, monitoring results can be combined with validated analytical design models and extensive material data. This enables precise recommendations that allow a more effective planning of specific lifetime measures such as continuous operation, repair, reconditioning or replacement of the rotor.

A living program

As part of our total gas plant portfolio, the Rotor Life Cycle Management program is continuously updated based on detailed analysis of operating data and inspection results from the entire fleet.

As a result the monitoring scope, schedule and the repair solutions portfolio are constantly optimized and the total life cycle costs are reduced while the rotor lifetime is fully enhanced.

Benefits

Based on a periodic creep and LCF monitoring schedule you will profit from:

- Specific recommendations for further rotor usage, to maximize lifetime without compromising the safety and reliability of each individually monitored rotor
- An optimized planning schedule for rotor monitoring, repair, reconditioning and replacement
- A dedicated on-site team of GE NDT specialists
- OEM engineering expertise for specific assessments and recommendations to support your long term capital expenditure and maintenance planning

Our commitment to lifetime extension never ends. For over 15 years we have provided sophisticated Rotor Life Cycle Management services on welded gas turbine rotors.

Rotor insights for life

Longevity from design to operations

Leading rotor expertise

With the largest services portfolio in the industry, we are renowned for design and operational expertise. Our welded rotor design delivers superior reliability and simplifies maintenance extensively.

The design advantage

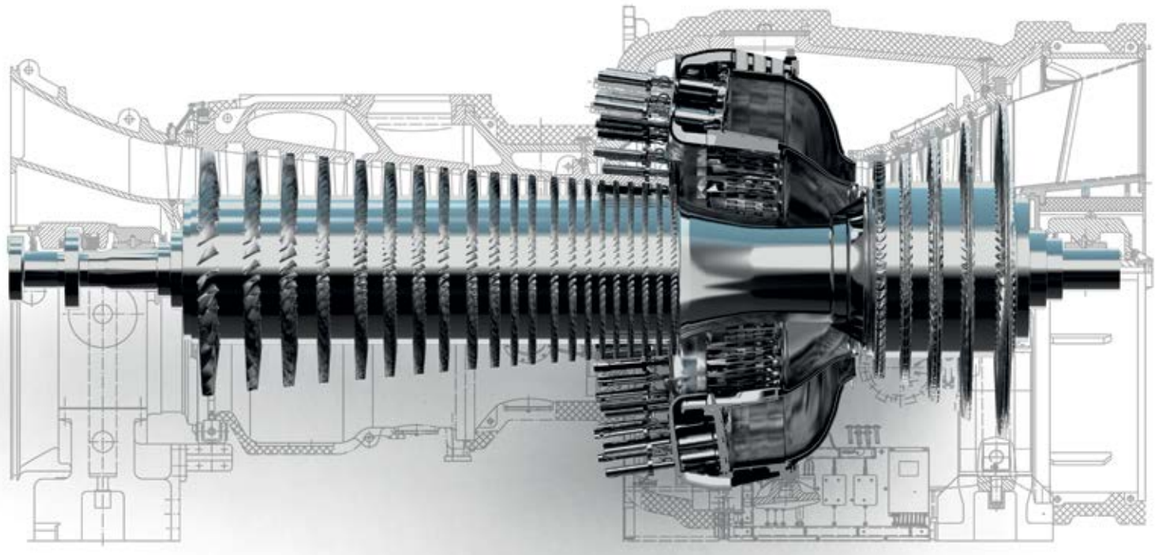
During rotor design, the latest analytical calculations techniques and extensive material testing are employed. Uncertainties regarding operational factors are addressed by individual component risk profiles. Testing and validation is performed through extensive programs involving overspeed testing in a spin pit, prototype instrumentation, validation in our test engine and accumulation of extensive field experience.

Reliability is enhanced by applying material choices, optimized for each rotor stage. This makes our welded rotors more robust, reliable and maintenance-friendly.

A solution for durability

Building on the design advantages of the welded rotor, we offer the Rotor Life Cycle Management program. It is an ideal way to maximize the rotor specific lifetime safely.

The Rotor Life Cycle Management program is available for GT8, GT9, GT11, GT13, GT24 and GT26 gas turbine rotors.



Robust and reliable – the welded rotor

The role of the operating regime

Base load and cyclic operation regimes lead to characteristic lifetime consumption encountered in gas turbine rotors.

Base load units

In base load units with few thermal cycles, the effects of centrifugal forces and consistent high temperature over thousands of operating hours dominate the lifetime consumption process. The predominant mechanism is creep – material elongation and deformation.

Creep effects are assessed with high resolution dimensional measurements conducted by GE specialists during each C inspection.

Cycling or peaking units

In cycling or peaking units that are frequently started and stopped, the primary aging process is caused by transient operations. The result is low cycle fatigue (LCF) – material weakening followed by the formation of tiny linear indications.

LCF effects are assessed using NDT methods such as advanced ultrasonic and/or eddy current testing.

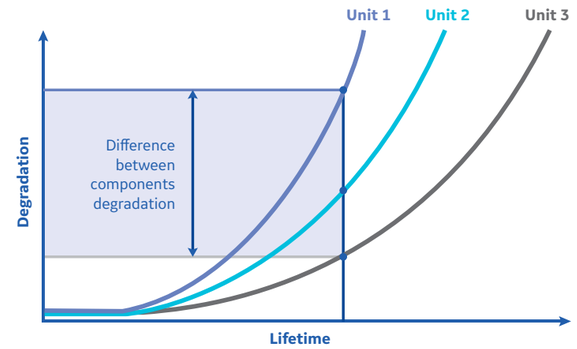
The number of accumulated starts determines the time to start LCF assessments.

In-service degradation

Besides the operation regime a number of additional factors interact and influence the rate of degradation of each individual rotor. These include:

- Environmental factors like corrosion and erosion
- Maintenance
- Material properties

Corrosion, for example, can cause additional stress concentrations in life limiting locations.



Varying operational factors lead to different degradation behavior

OEM and field competence at your service

Making rotors exceed expectations

Maximizing your specific rotor lifetime

Information gained about the specific rotor condition and its history improves the quality of decisions made throughout the rotor lifetime. This allows you to enhance the full lifetime potential of your rotor without exposing your plant to uncontrolled risks.

Minimum expected lifetime

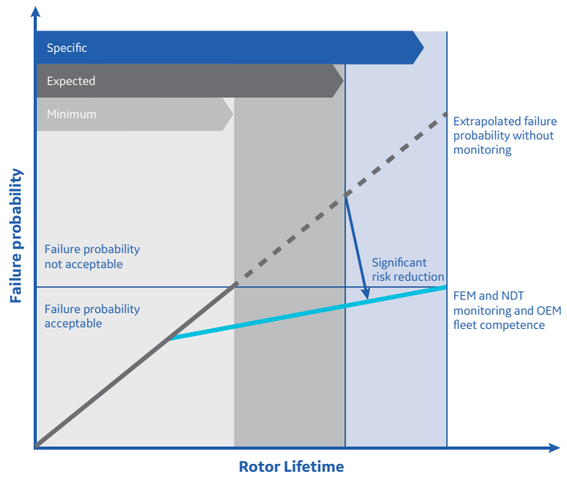
The minimum expected lifetime is defined in the lifetime sheets specific for each gas turbine type. It is general for the fleet. In order to achieve the Minimum Expected Lifetime, visual inspections are performed during a standard C inspection of the gas turbine.

Expected lifetime

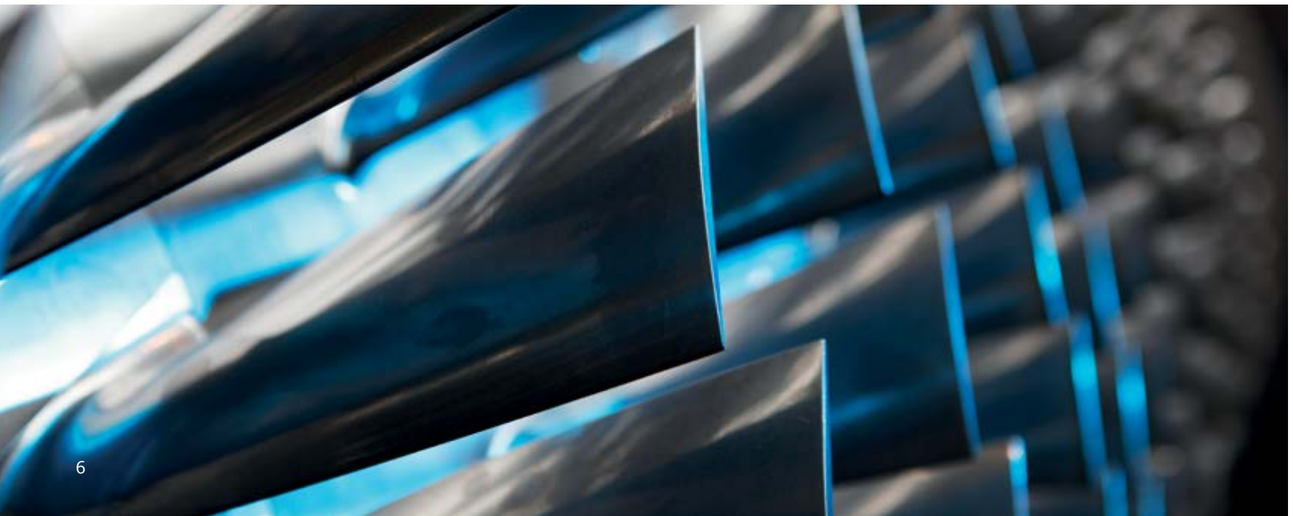
The expected lifetime is specifically defined for each engine/rotor type. Rotor monitoring according to the recommended schedule is therefore required. Potential on site/off site repairs can be performed during a C inspection of the gas turbine.

Specific lifetime

The specific lifetime is defined for each rotor individually. In addition to the implemented Rotor Life Cycle Management program, the specific condition and the planned future operation regime are taken into careful consideration for the individual recommendation.



OEM competence allows for maximum lifetime utilization at reduced risk



Optimizing the inspection and locations

All the locations to be inspected by GE's NDT methods are determined by finite element methods (FEM), material data and global field experience. This results in a very specific and optimized inspection schedule and scope that aims to deliver the most accurate and reliable recommendations.

Creep

In parallel to testing for low cycle fatigue, dimensional measurements are performed during C inspections to monitor creep degradation. The scope remains the same for each measurement.

Low Cycle Fatigue (LCF)

NDT inspection of the rotor for LCF allows for the detection of linear indication initiation and propagation. As the number of starts increases, the NDT scope is extended as more locations may become life limiting.

The results from both NDT inspections combined with our OEM knowledge and rotor history are used to predict the behavior of the indications found and to provide recommendations in the most accurate and reliable manner for further rotor use or planning of appropriate actions—such as further monitoring, repair or reconditioning/replacement.

With each subsequent inspection cycle and information gained for the specific rotor condition and operating data, the accuracy of the statements concerning lifetime expectations, maintenance planning and risk management increases.

GT24/GT26 indicative inspection schedule based on number of starts

- 1000S scope
- 2000S scope
- 3000S scope

Recommendations you can rely on

The iterative way

Plan

GE's Rotor Life Cycle Management program is based on regular rotor assessments performed during routine C inspections.

Based on a thorough prior review of the individual gas turbine rotor operation history, anticipated future operation regime and respective fleet data, a jointly agreed individual inspection schedule for creep and LCF assessment is defined.

The first assessment shall be made as early as possible to establish the reference level.

Monitor

The execution of the on-site rotor assessment is aligned with other C inspection work and is carried out by GE NDT specialists certified according to international standards and continuously trained.

Designed for purpose inspection probes, embedding advanced NDT technologies (details see page 10) are developed and validated for each specific inspection task to ensure the required measuring accuracy.

In a continuously evolving best practice approach, the resulting measurement data combined with OEM design information and fleet data is analyzed to make reliable and risk controlled recommendations for further rotor use.

Recommend

The Rotor Life Cycle Management recommendation report is the best basis for performing residual life analysis and making the decisions that allow you to maximize rotor lifetime.
The results of the regular investigations are stated in a detailed report after each assessment cycle—including the test certificates, presenting the results and the condition of the rotor. Most importantly, the Rotor Life Cycle Management report includes a recommendation for further operations which can be:

Continue operation
If there are no LCF findings or findings are well below the maximum allowable linear indication depth, the recommendation is to *continue operation* without limiting starts. The continue operation recommendation is also given when dimensional measurements have been performed but creep elongation is far from being at the limit.

Monitoring
In case of linear indications which are below the maximum allowable depth, an immediate repair may be sub-optimal from a schedule and cost perspective. Therefore, a recommendation may be given for further operation of the rotor with specific monitoring recommendations, potentially in combination with operational limitations.

Repair
If the rotor has deteriorated beyond the serviceable limit or if particular features are damaged, a repair will be recommended. Repairs can be carried out on site or in case of a more sophisticated repair, in one of GE's specialized workshops.

Reconditioning/replacement
Technical or economic constrains may eventually lead to a replacement. If the rotor turbine section is approaching its end of life (LCF and/or creep deterioration), it is possible for certain rotor types to replace the turbine section by a new one.

Having the detailed design and configuration knowledge allows GE to also provide recommendations about the interchangeability or upgradeability of rotors. This can be of a great benefit, in particular for customers operating several gas turbines of the same type.

Key customer benefits

- Maximized rotor lifetime without compromising safety and reliability
- Optimum planning for monitoring, repair and replacement
- OEM engineering support for specific assessments/recommendations
- Dedicated team of certified GE NDT specialists

Non-destructive technologies

Adding value to each inspection

Eddy Current

The main application of eddy current testing is to detect surface or near-surface flaws (typically a consequence of LCF for rotors in service) in conductive materials. A design-specific probe coil induces a magnetic field in the test material, which in turn produces electrical eddy currents that can be measured. The characteristic patterns of these eddy currents will be disrupted if any indications are present in the material. This method detects shallow, longitudinal indications with a high degree of accuracy and consistency.

Eddy Current Array

Eddy current array probes consist of multiple coils, which are grouped together to form an array. All coils can be driven individually depending on the application. This new technology allows testing a bigger area in a single pass which leads to shorter inspection times while assuring a full coverage of the inspected area.

Ultrasonic Phased Array

Phased array technique is the further development of the conventional ultrasonic testing. Multiple piezoelectric elements on the test head emit variably delayed ultrasonic impulses in a predefined sequence that results in a sound beam focused at different depths and angles. The echoes provide information about possible defects at critical locations including groove radii and inner cavities. It is employed to examine the condition of inner structures and detection of flaws at various subsurface locations.

Design specific Eddy Current probe – inspection of turbine radial grooves

Eddy Current testing of radial bore hole

Semi-automated Phased Array testing equipment

Dimensional measurements

Creep-life relevant locations are defined based on numerical rotor simulations that are continuously calibrated against fleet wide operating experience, while taking into consideration material properties, mechanical loads and rotor temperature profiles. Measuring and evaluating the dimensions of the critical zones requires specialized know-how.

Specialists at your service

The monitoring is performed by GE's certified NDT specialists during C inspections and needs to be planned within the outage preparation phase. Our NDT engineers are qualified and certified according to international standards of NDT. Personnel certification by accredited training and examination centers, combined with a solid engineering background, is a mandatory requirement. Regular internal training on gas turbines and material sciences complement the profile of a GE NDT specialist.

Sophisticated equipment

Whenever applicable automated scanning systems such as robots and/or encoded probes are used. The automated data gathering enables high reproducibility and repeatability as well as speed and data quality of the performed inspections. All inspection data is stored on our servers to allow monitoring from one inspection to the next and to compare gas-turbine-specific data individually with the entire fleet.

Creep measurement

NDT specialists with cooling cavity scanner

A comprehensive program

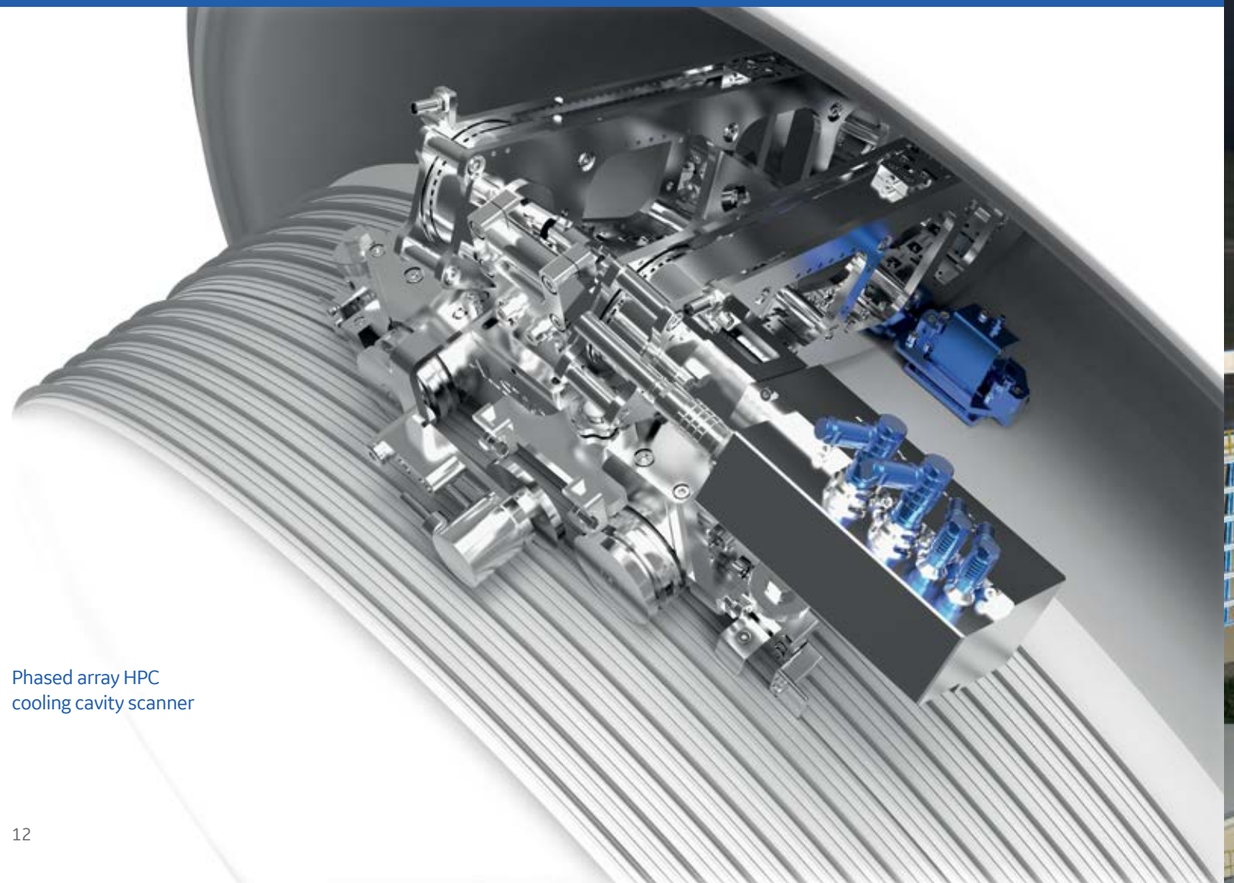
Powering rotor life cycle performance

Services designed to exceed expectations

With GE's Rotor Life Cycle Management program, your actual plant conditions and operating regime are taken into account. This allows you to enhance the full lifetime potential of your rotor without exposing your plant to uncontrolled risks.

Thanks to OEM insights, precise information about the rotor condition and trend-based predictions, you can take control of the maintenance schedule, reduce unplanned downtime and accurately orchestrate investments and maintenance work.

Understanding the life cycle of your rotor is instrumental in long-term planning of major maintenance. Partnering with GE provides you the full advantage of our global field expertise and allows you to define the best strategies to maximize availability at optimum costs.



Phased array HPC cooling cavity scanner

Power Service Digital Solutions

Imagine...

- Operating your plant and overall enterprise with predictive analytics securely, at scale
- Having the ability to see around corners and make your operational decisions proactively
- Attaining a consistent state of prime operational readiness
- Being able to monetize your plant operations, from asset to enterprise, by looking at one snapshot summary

All of this and much more is being unlocked in the power generation industry through the power of big data and the convergence of advanced computing, analytics and low levels of connectivity made possible by the Internet. These Industrial Internet capabilities are positioning plant and fleet operators to harness and monetize in ways like never before. One example is the Digital Power Plant, a suite of hardware and software solutions, which will enable our customers to optimize all the critical components to adapt to changing market conditions.

Power Services is focused on how to help our customers achieve their needed outcomes—it is fueling the evolution of our new software solutions portfolio. This platform of apps and analytics can empower you to break through new barriers in performance, predictability, and profitability.

Total Plant Solutions

When it comes to optimizing the performance and long-term value of your gas power plant, imagine....

- Having the support—and continuity—of a single service provider that understands the full plant-as-a-system impact for all your installation, maintenance, repair and upgrade activities
- Fully harnessing the synergies within all the interconnected systems across your operations
- Teaming with one partner that has the flexibility to solve any combination of needs—and support any asset mix—throughout your plant's life cycle

Driven by 230 years of total power generation services experience, the Power Services portfolio stretches across the horizon of total power plant capabilities.

While delivering tailored solutions for all major components—like gas turbines, steam turbines, generators, HRSG or Balance of Plant—Power Services' total gas plant portfolio of solutions stretches across numerous OEM brands for:

- Planning and installation
- Maintenance and repairs
- Monitoring and diagnostics
- Advanced technology upgrades and flexibility solutions
- Outcome-based service agreements
- Scalable plant-level solutions
- Plant recommissioning/relocations

Our broadened understanding of system-wide operations is applied to help customers unleash better performance, lower risk and realize greater value from their plant and fleet assets.

- Power Services delivers plant solutions for 90+ OEM brands
  - World's largest installed base of 8,000+ gas turbines globally
  - Solutions for our global fleet of 9,900+ generator assets
  - Operational experience from >700 supplied HRSGs
  - Steam turbine portfolio that supports 80 OEM brands (400+ upgrades completed on other OEM brands)
- Power Services supports our customers with ~26,000 people in 150 countries
- Our repairs network features 50+ shops located in 25 countries
- Our team has 120+ million hours of operating data on which to develop digital solutions
- We have one of the world's largest fleet of monitored gas plant assets ~3,200

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