

**AUTOMATED RESIDUAL  
STRESS ANALYSIS**

# **X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT TURBINE ENGINES**



PHOTO COURTESY OF USAF

*A world of solutions*



# X-RAY DIFFRACTION

## OPTIMUM COMPONENT & PROCESS DESIGN

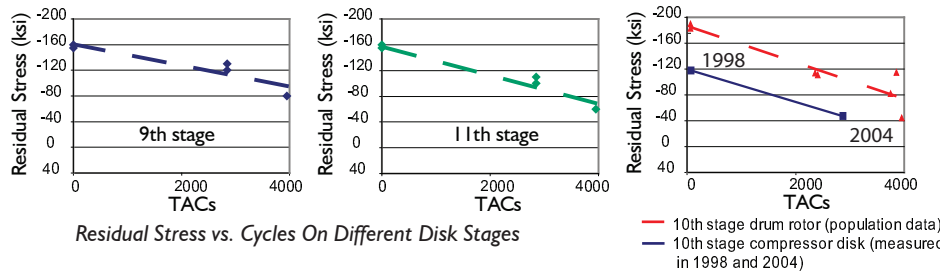
Achieving full material potential requires quantitative measurement of residual stress for each individual component.

“Design to RS, Produce to RS and Manage to RS” is an enhancement concept to help achieve reduced component weight, improved life expectancy and lower maintenance costs. Achieving the full material potential, from alloys used in turbine components, requires measurement of failure critical areas on the “as manufactured” parts and monitoring these residual stresses throughout service life. The residual stresses must be measured to ensure beneficial stresses are present while detrimental stresses have been reduced or minimized.

## LIFE PREDICTION ENHANCEMENT: TRACKING LCF

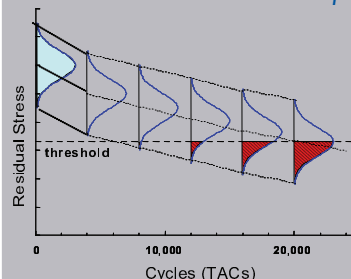
Residual stresses can be an indicator of component life.

During the past five years, Proto has had the opportunity to measure RS on hundreds of turbine engine rotating components. Although the database of RS information is already sizable, considerable work lies ahead to expand this body of knowledge. Trends have been observed in the relaxation of RS with cycles and it is expected in the near future that such quantitative RS data will be used to enhance life prediction methodologies. Residual Stress Measurement is expected to be used as an important non-destructive determinant for life management decisions on in-service aero engine components subject to LCF.



Tracking residual stress of serialized critical components from the day they enter service and throughout their service life allows creation of a database to enable removal of parts for either reprocessing or retirement instead of entire populations. Engines can be rebuilt with critical parts with similar remaining life to optimize overhaul intervals. Life extension can be granted to components that have substantial RS credit. In addition, providing such information would allow a longer lead time and more efficient prediction of replacement part requirements.

### RSM<sup>®</sup> Patented Disk Life Extension: Licensing Opportunities Available



- Database tracks relationship between Residual Stress Measurement (RSM<sup>®</sup>) and fatigue cycles (TACs).
- Evaluate health of each disk on its own merit and relationship within the statistical population.
- Remove disks with RS below the “threshold” as they are at risk to initiate a crack in the next service interval.
- Return disks to service with RS above “threshold”.

## HISTORY

Since its founding in 1968, Proto Manufacturing (Proto) has been involved in the development and application of non-destructive evaluation (NDE) technology.

In the early eighties, Proto recognized that many of the problems requiring the palliative application of NDE had undesirable residual stresses as their root cause. It was reasoned that measurement and management of residual stress could prevent these problems altogether, or at least more efficiently direct additional NDE efforts.

Proto selected x-ray diffraction (XRD) technology because of its promise for providing quantitative measures of residual stress (RS) both safely and non-destructively. Proto set a goal to develop XRD technology sufficiently to allow practical problem solving in laboratory, factory and field environments.

A continuous and considerable development effort has over the years succeeded in advancing the state-of-the-art to achieve this goal.

It is safe to say that Proto's XRD systems are the lightest, fastest and most advanced in the world today and are successfully applied in many sectors; aerospace (including military and civil) automotive, marine, power generation, nuclear and structural. These experiences have led to Proto's vision of bringing RS measurements using XRD to the OEMs and users of aero engines.

# FOR THE LIFE MANAGEMENT OF TURBINE ENGINES

## PRODUCTION QUALITY: NONDESTRUCTIVE & QUANTITATIVE

Residual stress can be used for controlling production quality on the factory floor by detecting abusive machining, verifying effects of surface enhancements and evaluating heat treat effectiveness.

### Verify Surface Enhancements

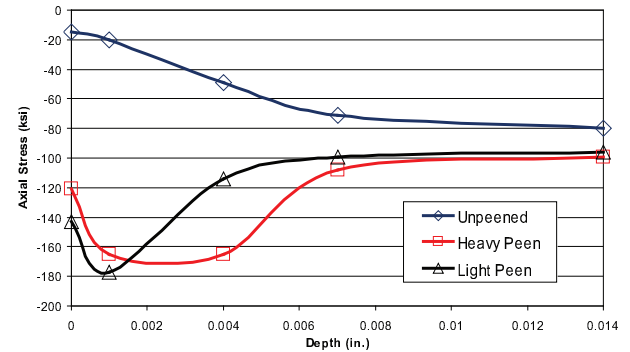
Turbine components often have complicated geometries that are enhanced by shot peening and other processes. XRD residual stress measurements can be used to verify that these locations have been enhanced to the specified residual stress level. A residual stress value, once established, can be specified on the engineering and processing documents and will attach an engineering value in stress rather than an Almen strip number designation.

### Identify Abusive Machining

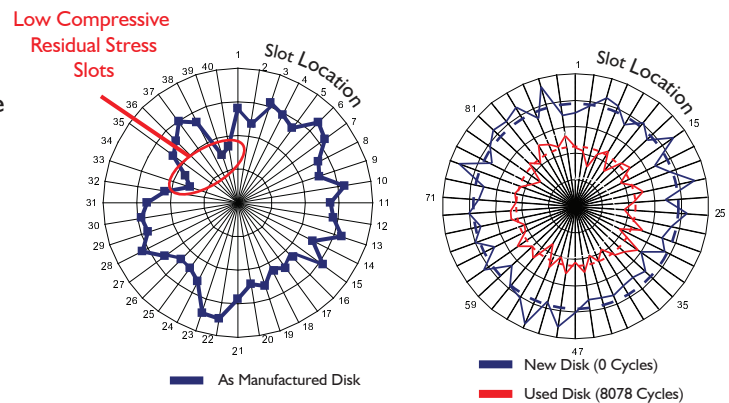
Machining can cause significant variations in the final residual stress state of a machined turbine component. XRD can be used to determine if any machined areas were subjected to abuse due to excessive tool wear, intermittent lack of cooling or aggressive machining practices. Abusive machining can create regions of tensile stress that could then become a potential source of crack initiation.

### Evaluate Heat Treat Effectiveness

XRD can be used to determine that heat treatment processes are being applied correctly. Post heat treatment XRD residual stress measurement of components can ensure that residual stresses are being managed correctly thereby reducing issues such as distortion during machining or cooling strains.



Residual Stress vs. Depth on Shot Peened Samples.

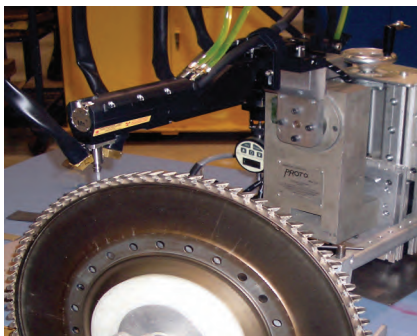


Residual Stress Maps of Blade Retention Slots

## MAINTENANCE IMPROVEMENTS

### Prevent overpeening of disks during overhaul.

Some in-service disks are shot peened during overhaul maintenance in an attempt to rejuvenate them. However, the residual stress level before the treatment is usually unknown and this could, unknowingly, have a deleterious effect on individual disks, especially if the disk is overpeened. The ability to measure residual stress enables maintenance staff to exercise better control and rework disks on a selective basis.



Measuring Residual Stress in a Blade Retention Slot.



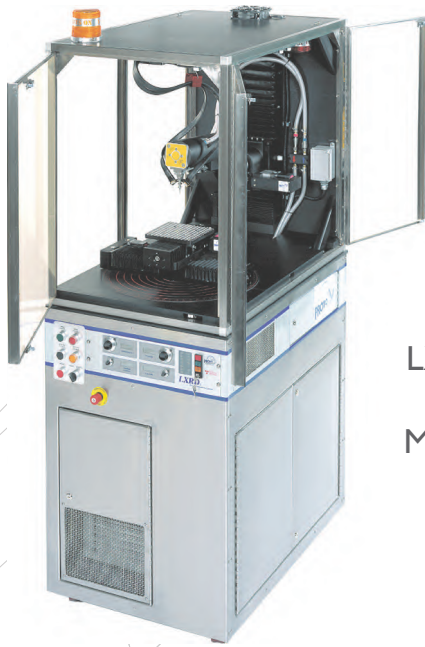
Measuring Residual Stress Inside A Bolthole



Measuring Residual Stress inside a Bore

# LIFE MANAGEMENT OF TURBINE ENGINES

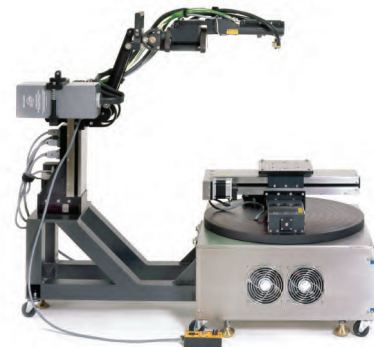
## AUTOMATED X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT SYSTEMS AND SERVICES



LXRD - LABORATORY  
RESIDUAL STRESS  
MEASUREMENT SYSTEM



iXRD - PORTABLE AND  
INLINE RESIDUAL STRESS  
MEASUREMENT SYSTEM



Modular Residual Stress Mapping



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