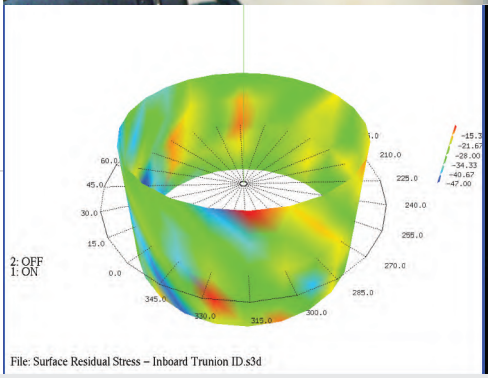
PROTO Manufacturing

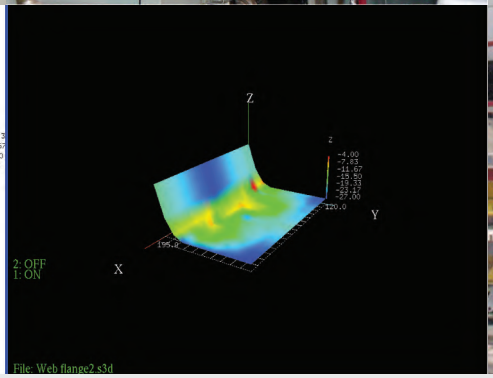
Automated XRD Systems & Service

AUTOMATED RESIDUAL STRESS ANALYSIS

X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT

CONDITION-BASED MAINTENANCE





A world of solutions

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.

RESIDUAL STRESS MEA

THE IMPORTANCE OF MEASURING RESIDUAL STRESS

Why Residual Stress?

All components have residual stress. These internal stresses develop when a component is manufactured and can be detrimental or beneficial to the fatigue life of a component. Residual stress plays an important role in stress corrosion cracking, distortion, fatigue life, cracking initiation, crack propagation, damage tolerance, premature failures in components, and instances of over design. As a result, manufactures take special care in ensuring that the correct level of residual stress is present in a component; especially at failure critical locations. Through out the service life of a component the residual stress state may change due to external cyclic loading, of the component. Monitoring the changes in the residual stress can be an extremely useful tool for determining the effective "health" of each component. In components where the residual stresses remain relatively constant, quantifying the level of residual stress is still necessary, since it affects crack initiation potential and crack growth rates.

An Advanced Tool for Condition-Based Maintenance.

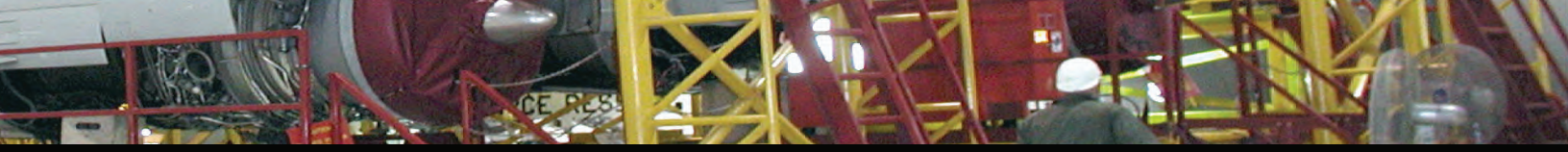
CBM requires tools that can directly monitor individual components and determine their effective health. Residual stress measurement provides a key quantitative piece of data to help make sound engineering decision as to the remaining life of a component. One advantage is that this data is directly measured on the component and not deduced from sensors in the surrounding environment.

Full Life and Life Extension Programs.

Existing lifing models rely on statistical data from a population to determine the time when a component must be replaced. However, early failures by even a few components require retirement of the entire population. Residual stress measurement enables better sorting of components prior to entering service and ensure that "early failure" parts with sub-par residual stress never enter service. In-service components can be monitored and only retired when a critical level of residual stress is reached. This "retirement for cause" model improves cost savings, provides for better spare part availability and improves the reliability of in-service parts.

Proto Manufacturing - Your Residual Stress Measurement Solutions Provider

Currently, the x-ray diffraction technique is the most accurate and reliable method used to measure residual stresses. At Proto Manufacturing, we manufacture a comprehensive line of x-ray diffraction systems, provide residual stress measurement services, and residual stress measurement consulting for a wide range of customers. Over 25 years of experience in the residual stress measurement field, has given us the tools and resources, to solve even the most demanding problem.

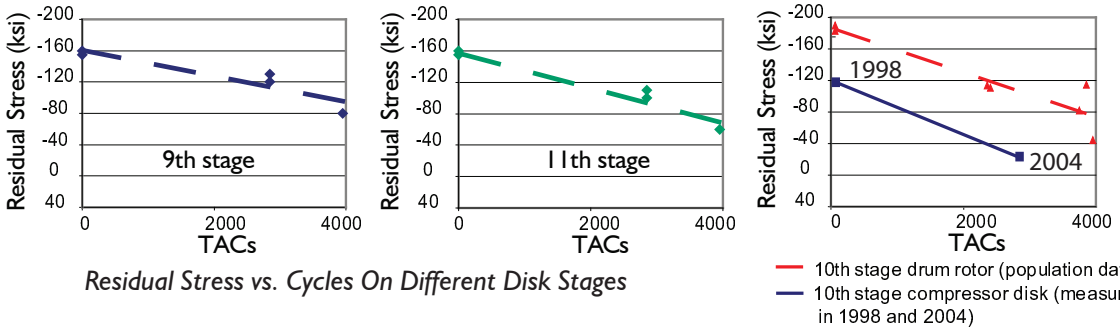


ASUREMENT AND CONDITION-BASED MAINTENANCE

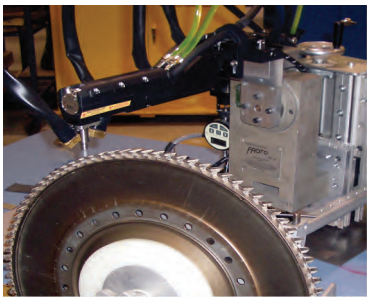
LIFE PREDICTION ENHANCEMENT: TRACKING LCF

Residual Stress - An Indicator of Component Life.

Proto has had the opportunity to measure residual stress on hundreds of turbine engine rotating components. Trends have been observed in the relaxation of residual stress with cycles at failure critical locations. This quantitative residual stress data can be used in two key ways: 1) to enhance life prediction methodologies and 2) to be used as a non destructive tool for life management decisions on in-service aero engine components subject to LCF.



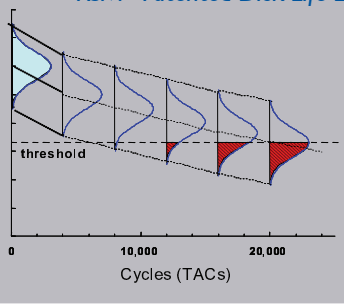
Residual Stress vs. Cycles On Different Disk Stages



Measuring Residual Stress in a Blade Retention Slot at the Depot

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 residual stress credit. In addition, providing such information would allow a longer lead time and more efficient prediction of replacement part requirements.

RSM© Patented Disk Life Extension: Licensing Opportunities Available



- *Database tracks relationship between Residual Stress Measurement (RSM©) 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".*

IMPROVING MAINTENANCE AND REPAIR RELIABILITY

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.

Detecting Areas on Airframes That Have The Most Potential for SCC.

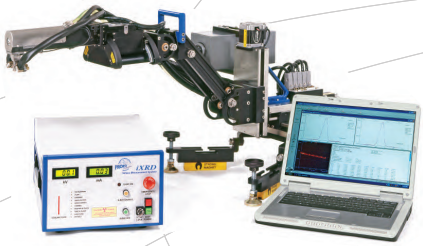
Airframes subject to SCC can be tested for the presence of tensile residual stresses. For SCC to occur a tensile residual stresses must be present at the surface of the structure. Identifying these susceptible areas allows subsequent non-destructive evaluation (such as ultrasonic crack detection) to be focused on these "hot" areas, thereby reducing costs and making more efficient use of inspection time.

Validate Repairs

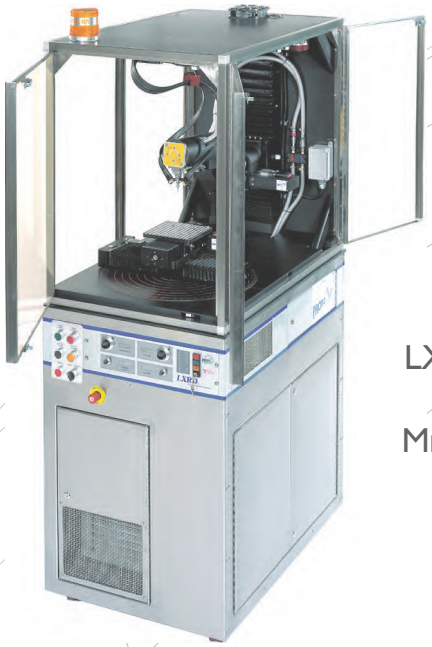
Components that have under gone a repair such as a weld repair, can be validated to ensure that the residual stress state is consistent with the original residual stress state expected by a "new" component. Validation that a part is geometrically correct is not sufficient to ensure a part will not fail. Since residual stress plays such an important role in the fatigue life of a component. Characterizing the residual stress state in the repaired component is necessary to ensure that the component will achieve the expected life.

CONDITION-BASED MAINTENANCE

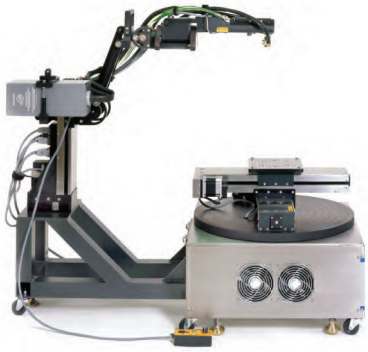
AUTOMATED X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT SYSTEMS AND SERVICES



iXRD - Portable and Inline Residual Stress Measurement System



LXRD - Laboratory Residual Stress Measurement System



Modular Residual Stress Mapping

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