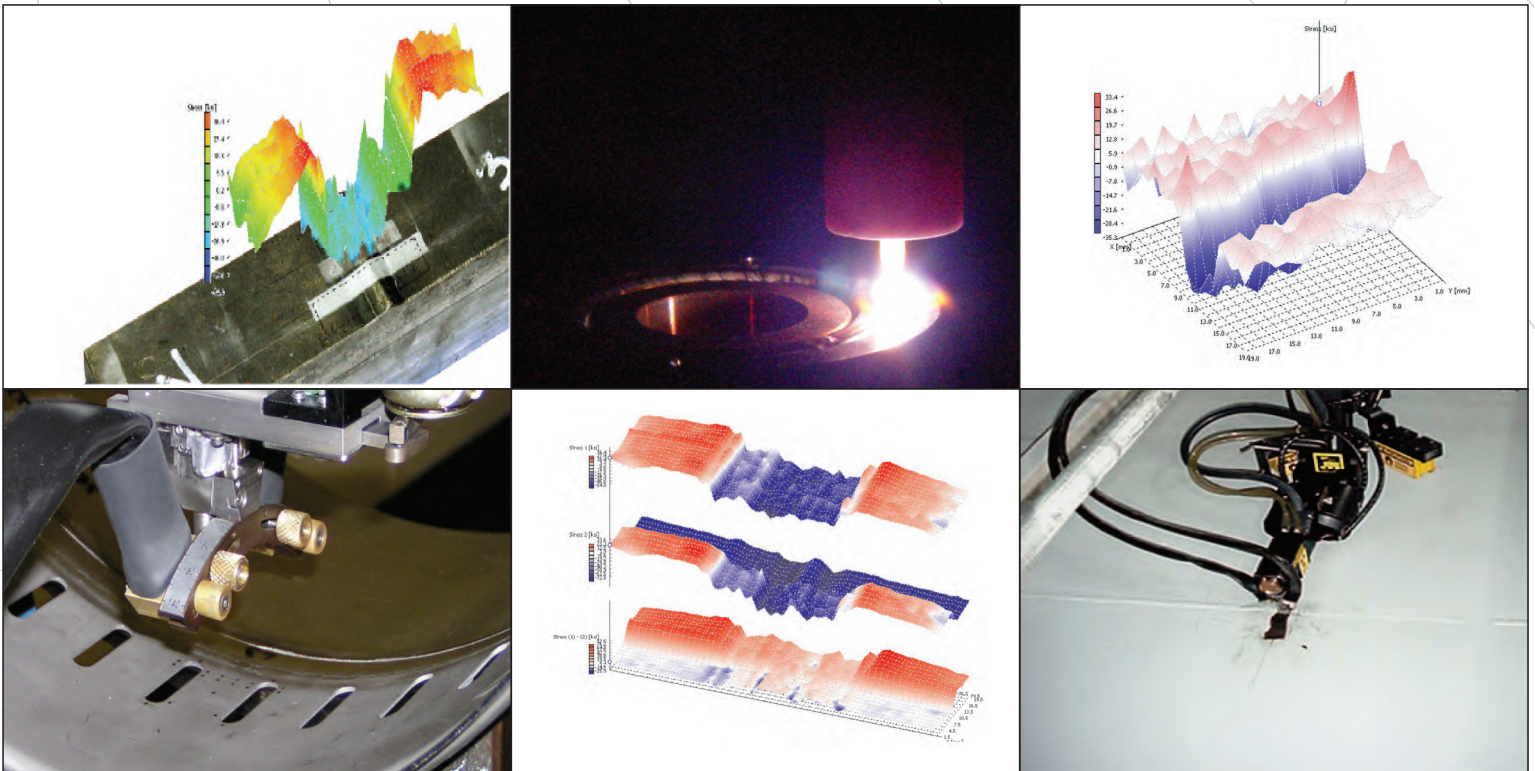


**AUTOMATED RESIDUAL
STRESS ANALYSIS**

X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT WELDS



A world of solutions

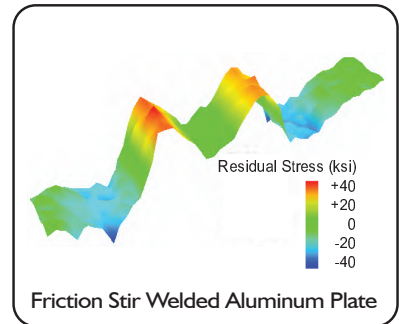
WELDS

Measuring Residual Stress in Welds

Residual stresses created during the welding process can lead to stress corrosion cracking, distortion, fatigue cracking, premature failures in components, and instances of over design. The nondestructive nature of the x-ray diffraction technique has made the residual stress characterization of welds a useful tool for process optimization and failure analysis, particularly since components can be measured before welding, after welding and after post-welding processes.

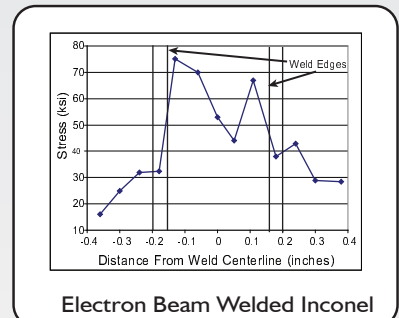
Managing Residual Stress

Numerous techniques such as heat treating and shot peening are available to help manage potentially harmful residual stresses created during the welding process. Knowledge of the residual stress state is required to ensure that these post welding processes have been correctly applied.



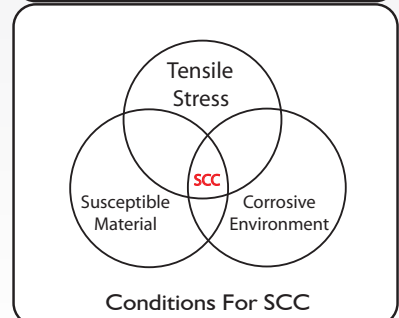
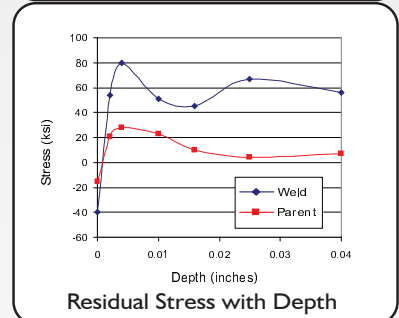
Fatigue Life and Stress Concentrations

The residual stress state in weld toes and undercuts are critical when stress concentration geometries exist that can magnify the effects of applied loads. When issues of fatigue cracking are considered, potentially harmful tensile residual stresses alone or in combination with stress concentrations can lead to fatigue crack initiation and propagation.



Stress Corrosion Cracking (SCC)

SCC is a major source of potential failure in welds. Most often, SCC occurs in the heat affected zone (HAZ) immediately adjacent to a weld since the HAZ is left in a state of very high residual tensile stress as a result of the shrinkage and differential cooling occurring in most welds. Tensile stresses (residual or applied) are the main component of the stress corrosion cracking triangle. The other two are a susceptible metal and an environment that often needs to be only slightly corrosive to that metal.



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.

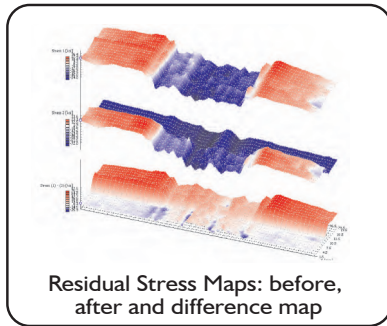
A continuous and considerable development effort has over the years succeeded in advancing the state-of-the-art to achieve this goal.

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, medical, power generation, nuclear and structural.

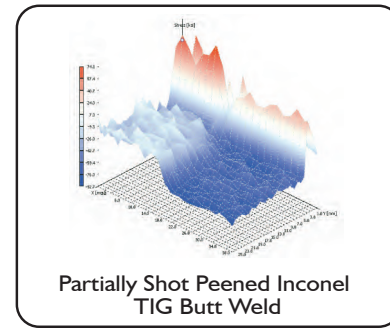
X-ray Diffraction Residual Stress Measurement

Residual Stress Mapping

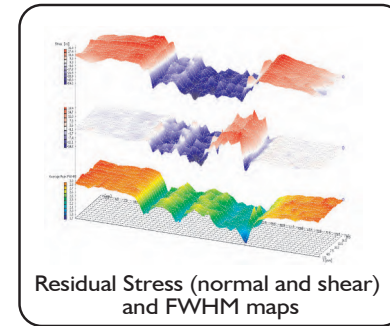
Proto's patented Automated Residual Stress Mapping technology can generate a comprehensive picture of the residual stress state of any sample. Even curved surfaces such as welds can be automatically mapped allowing designers and engineers to visualize and manage problem areas.



Example of a residual stress multi-map with a third "difference" map plotted by applying map algebra to the first two maps collected on the same weld before and after the weld was partially shot peened. This map overlaps the interface where the weld was shot peened and masked (i.e. not shot peened).



Example of a residual stress map on a partially peened Inconel plate weld.



Example of a multi-map with residual normal stress, shear stress and FWHM maps superimposed or "stacked".

Heat Treatment

Heat treatment processes are also commonly applied to welds to lower or reduce the residual stresses present in the weld and HAZ. Residual stress measurement can be used to ensure that such processes have been correctly applied and that any harmful residual stresses have been reduced to an acceptable level.

Finish Machining

Aggressive or abusive post-welding machining can create regions of tensile stress that can make the weld area susceptible to crack initiation and increase the rate of crack propagation.

Post-Weld Processes

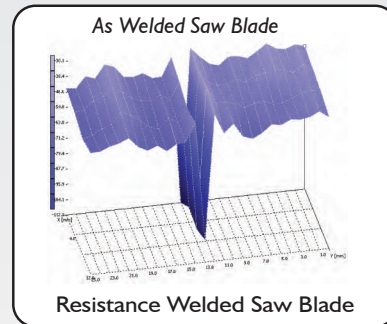
An effective way to manage the residual stresses in welds is to cold work the weld using a process such as shot peening. Residual stress measurements can be performed to ensure that tensile residual stresses have been reduced and beneficial compressive residual stresses have been introduced.

Validation of Finite Element Models

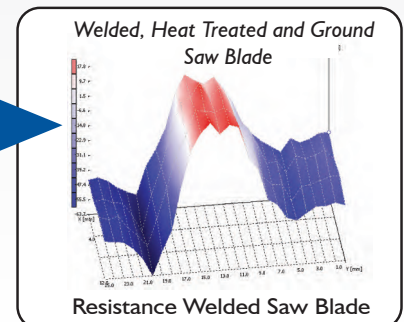
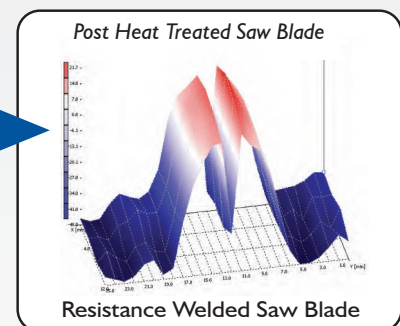
Much time and effort is spent modeling the residual stress state of welds. Residual stress measurement can be used to verify that these models are correct and improve models that have deficiencies.

Design Improvements

Utilizing a "Design to RS, Produce to RS and Manage to RS" philosophy helps to achieve reduced component weight, improve life expectancy and lower manufacturing and maintenance costs.

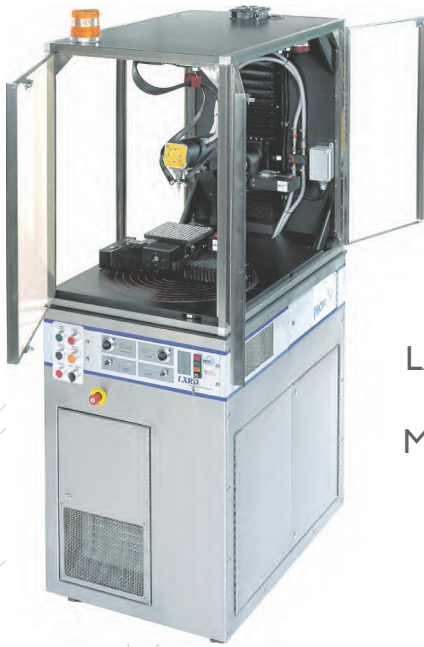


Measuring residual stress throughout the manufacturing process yields quantitative data that can be used to enhance each step.



WELDS

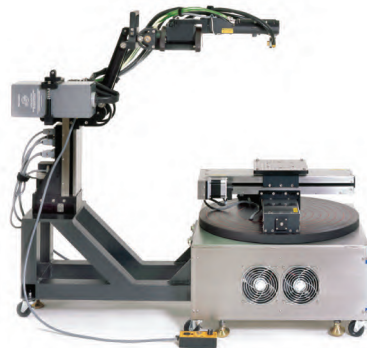
AUTOMATED X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT SYSTEMS AND SERVICES



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Modular Residual Stress Mapping



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