Diffraction Notes

LAMBDA RESEARCH 5521 FAIR LANE CINCINNATI, OH 45227 (513) 561-0883 NO. 21 ANNUAL, 1997

LAMBDA'S YEAR IN REVIEW

TEXTURE AND PHASE ANALYSIS LABORATORY

Lambda Research recently completed a study which verified the importance of performing **retained austenite** measurements in strict accordance with ASTM E975--"R" values must be calculated from the crystal structure and unit cell dimensions of the alloy for both the austenitic and martensitic phases using the unit cell dimensions and chemistry in accordance with SAE SP-453. Using standards manufactured from other alloys to "calibrate" by reverse solution can result in large errors, on the order of 20% of the austenite content reported, because of the inability of the "standards" to accurately reflect the unit cell dimensions and chemical composition of the austenite and martensite phases found in the subject steel.

Software was also implemented to allow **retained austenite** measurement using either a constant area or a constant angle technique. The constant area method allows measurement on samples too small to practically contain the incident x-ray beam or on large numbers of small specimens, such as wire, shot, etc.

Lambda Research has developed laboratory procedures for the quantitative analysis of **monoclinic and cubic components in yttria-stabilized zirconia**. Typically, the material is used in either monolithic or plasma-sprayed forms in medical, automotive, and aerospace applications. Our method of analysis is based on that of Garvie and Nicholson (J. Garvie and P. Nicholson, *Journal of the American Ceramic Society*, vol. 55, 1972, pp. 303-305).

A technique for the determination of **Ca/P ratios** for **hydroxylapatite (HA)** sintered material has been developed based upon x-ray diffraction rather than fluorescence methods. Provided the material is entirely crystalline, the procedure, derived from the phase composition, provides an order of magnitude higher precision than could be obtained using fluorescence techniques on powder material.

Lambda Research has refined **texture analysis** methods using both **pole figures** and **orientation ratios** to determine the texture in sputtering targets. Orientation ratios, pole figures, and ODF studies have been performed in a wide variety of metals, including nickel, titanium, aluminum, cobalt, and gold.

RESIDUAL STRESS LABORATORY

During 1997, Lambda Research refined its **finite element method** for correcting stress relaxation during layer removal. Lambda's correction method, which can be applied to complex geometries and arbitrary stress fields, is an improvement of the work of Moore and Evans (M.G. Moore and W.P. Evans, "Mathematical Correction for Stress in Removed Layers in X-Ray Diffraction Residual Stress Analysis, SAE Transactions, Vol. 66, 1958, pp. 340-345), which could be used only for subsurface measurements in flat plates, cylinders or tubes having simple stress states. The new method was tested by comparing it to the Moore and Evans closed form method using a two-dimensional finite element model of a flat plate and cylinder. The techniques were in excellent agreement. Lambda's FEA correction is more generally applicable, as it is well suited to actual components, such as gear teeth, turbine blades, bearing races, and cam lobes, etc.

Lambda Research has continued to refine and develop methods of estimating **yield strength gradients** based on the relationship between true plastic strain and x-ray line broadening data. Machining processes as well as surface enhancement techniques, such as shot peening, will create a plastic strain gradient near the surface. The plastic strain, or percent cold work, can be determined through the x-ray line broadening data. By using a true stress-strain curve, the yield strength can be determined from the percent cold work. Using this procedure, the percent cold work and yield strength gradients can be determined as a function of depth. Techniques have been established for developing calibration curves and measurement in a variety of nickel, aluminum, and titanium alloys and austenitic stainless steels. Practical applications include failure analysis and process development.

For more information about our testing capabilities, accreditations, or other publications, visit our website at www.lambda-research.com.

Lambda has developed the **StressPro,**℠ a fully automated apparatus for obtaining residual stress profiles--as many as two per hour. Patent application for the apparatus is pending and is expected to issue in 1998. The device rotates two specimens alternately into position for measurement and layer removal. Residual stress distributions are generated at depths which are predetermined by computer. All data are corrected for x-ray beam penetration and stress relaxation. StressPro℠ is available for use as a quality control and process development tool for refining shot peening, grinding, induction hardening, and similar manufacturing processes where residual stress development is critical to component performance.

Computer-controlled sample positioning apparatus and data reduction software were developed by Lambda engineers to enable **mapping of residual stress distributions**. Stress distributions can be mapped both on a surface and as a function of depth with finite element techniques used for correcting for stress relaxation in complex stress distributions and geometries. Laser shock distributions around individual spots, complex stresses at weld intersections, and similar features have been mapped to date in a variety of alloys. Results can be presented as contour plots or three-dimensional presentations. The technology is being used to refine finite element-based residual stress prediction software for welding and laser shocking.

Lambda Research can be reached on-line at **www.lambda-research.com**. The website contains valuable information, such as single-screen descriptions of each of our capabilities, as well as our many publications which will soon be available for direct download. In the event you have any technical questions concerning our capabilities or wish an engineer to contact you regarding a possible workscope, you may leave an e-mail message on-site.

Glenn A. Plunkett and Douglas J. Hornbach are the two recipients of Lambda Research's **Engineering Advancement Award** for 1997. This is earned for exceptional personal achievement resulting in the advancement of the science and engineering of materials testing. Glenn Plunkett was recognized for his original contributions in the development of automated apparatus for residual stress mapping on the surface and with depth. Doug Hornbach was recognized for his original contributions in the development of center hole-drilling residual stress measurement technology for orthotropic materials.

TECHNICAL CONTACTS

Paul S. Prevéy, Director of Research
Doug Hornbach, Supervisor of Residual Stress Lab
Perry Mason, Supervisor of Texture & Phase Analysis Lab
Beth Shoemaker, Staff Geologist

PRESENTATIONS AND PUBLICATIONS

Engineers at Lambda Research have co-authored and/or presented a number of papers at various proceedings during 1997.

- **"Tensile Residual Stress Fields Produced in Austenitic Alloy Weldments,"** co-authored by Doug Hornbach and Paul Prevéy. Presented at ASME International's Energy Week Conference, January 28-30, 1997 in Houston, Texas, the paper discusses a combined x-ray diffraction and mechanical technique which was used to determine the axial and hoop residual stress, cold work, and yield strength distributions into the inside diameter of a simulated Alloy 600 penetration J-welded into a reactor pressure vessel.

- **"Residual Stresses in OTSG Tube Expansion Transitions,"** co-authored by Doug Hornbach, P. A. Sherburne, B. A. Ackerman, and A. R. McIlree. The paper, presented at the Eighth International Symposium on Environmental Degradation of Materials in Nuclear Power Systems--Water Reactors, August 10-14, 1997 in Amelia Island, Florida, discusses the residual stress and cold work distributions in a failed OTSG tube measured by x-ray diffraction and finite element analysis.

- **"Thermal Residual Stress Relaxation and Distortion in Surface Enhanced Gas Turbine Engines,"** co-authored by Paul Prevéy, Doug Hornbach, and Perry Mason. The paper, presented at ASM Materials Week, September 15-18, 1997 in Indianapolis, discusses the thermal relaxation of the compressive layer developed by shot peening, gravity peening, and laser shocking Ti-6Al-4V and Inconel 718 at engine temperatures.

- **"Development of Machining Procedures to Minimize Distortion During Manufacture,"** co-authored by Doug Hornbach and Paul Prevéy. Presented at ASM Materials Week, the paper discusses typical residual stress distributions seen in heat treated components and how finite element models may minimize distortion.

- **Residual Stress Measurement as a Tool in Failure Investigations**, presented by Paul Prevéy at ASM Materials Week. This presentation covered the sources of residual stress, various methods of measuring residual stress, especially x-ray diffraction, hole drilling, and the ring-core method, and the primary modes of failure which are influenced by failure analysis.

To receive copies of these publications or further information on new technologies, please contact Kathleen Bauer in Customer Service.