Diffraction Notes

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LAMBDA RESEARCH INC. 1111 HARRISON AVENUE CINCINNATI, OH 45214 (513) 621-3933

SIMULTANEOUS DETERMINATION OF RESIDUAL STRESS AND HARDNESS IN STEELS

X-ray diffraction can be used to determine, simultaneously and independently, both macroscopic and microscopic residual stresses. Macrostresses extend over distances large compared to the grain size, causing uniform strain in all of the diffracting crystals and a shift in the diffraction peak angular position. Microstresses arise from local strains, due to imperfections within the crystal lattice of individual grains, and produce a broadening of the diffraction peak.

Macrostress is a tensor property, which varies with direction, and is equal to the sum of the residual and applied stresses present in the irradiated area. Diffraction peak broadening, produced by microstresses, can be treated as a scalar property, dependent upon the average perfection of the diffracting crystals. Diffraction peak width can be used to quantify the degree of cold work produced by plastic deformation associated with machining, grinding, or shot peening. In martensitic steels, the martensite phase transformation produces microstresses and line broadening, which can be related directly to hardness.

Using Pearson VII functions to separate the K-alpha doublet used for residual stress measurement, it is possible to determine independently both the angular position and width of the K-alpha 1 diffraction line.[1] An empirical relationship can be established between the (211) diffraction peak width and hardness, using a series of coupons of the alloy of interest, heat treated to produce a range of hardness. The relationship between the width of the K-alpha 1 (211) diffraction peak and Rockwell "C" hardness, for two different heats of M50 steel, is shown in Figure 1. The curve, fitted by least squares regression, allows hardness to be calculated from the (211) peak width. Similar curves have been established for several steels, to date.

The relationship between peak width and hardness is highly dependent upon the carbon content. Therefore, calibration curves must be established for each alloy, and the technique is not applicable to carburized steels. Even when conversion to hardness is not possible, the peak width alone can provide valuable information.

A seen from Figure 1, the peak width is a sensitive function of hardness in the high hardness range. Because the peak width can be determined to an accuracy on the order of ± 0.02 deg., very small changes in hardness, on the order of 0.1 HRc, can be detected in fully hardened materials. The small depth of penetration of the x-ray beam allows slight reductions in surface hardness, due to decarburization or plastic deformation of martensitic steels, to be measured with a depth resolution on the order of 0.0001 in.

An example of the simultaneous determination of residual stress and hardness in an M50 steel component is shown in Figure 2. Lambda Research now includes the diffraction peak width with all residual stress measurements.

REFERENCES:

1. P.S. Prevey, "The Use of Pearson VII Distribution Functions in X-ray Diffraction Residual Stress Measurements," Vol. 29, ADVANCES IN X-RAY ANALYSIS, 1986, pp.103-112

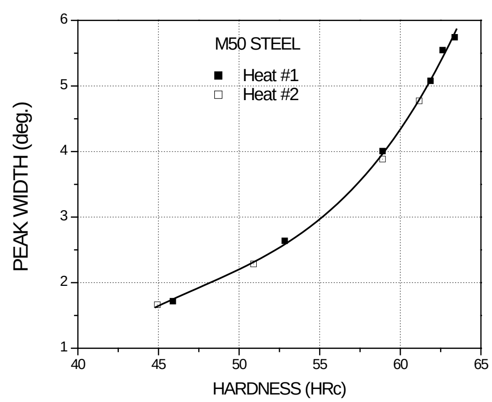

Figure 1

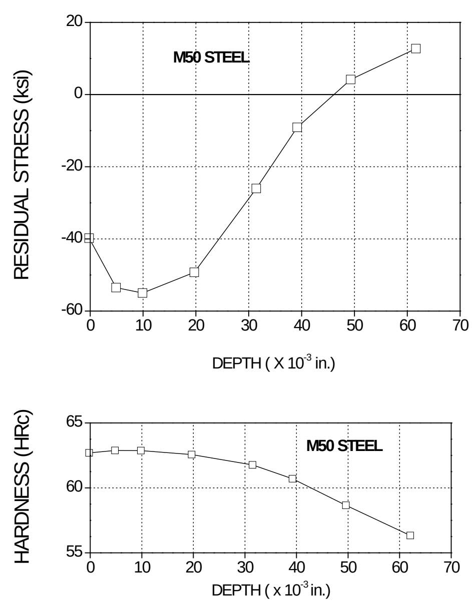

Figure 2

LABORATORY AUTOMATION

Lambda Research is pleased to announce full automation of the x-ray diffraction laboratory. All four diffractometers are now under the control of a central super-microcomputer system utilizing the Motorola 68000 microprocessor for data collection and reduction. Software has been developed for residual stress measurement, retained austenite determination, qualitative phase analysis, and pole figure determination. Software is under development using Pearson VII functions for improved determination of peak position and line broadening in residual stress measurement, integrated intensities in retained austenite determination, and separation of overlapping peaks in qualitative and quantitative analysis.

Automation of the diffractometers virtually eliminates errors in data acquisition, standardizes test procedures, and improves both measurement repeatability and laboratory efficiency. The resulting increased testing capacity has reduced our backlog and improved delivery.

ASM HANDBOOK, VOL. 10, MATERIALS CHARACTERIZATION

The American Society for Metals has published Volume 10 of the ASM Metals Handbook Series entitled, **MATERIALS CHARACTERIZATION**. In a chapter on “X-ray Diffraction Residual Stress Techniques,” contributed by Paul Prevey of Lambda Research, the theory, areas of application, sources of error, and examples of the use of x-ray diffraction residual stress measurement are described in a format designed to provide a rapid assessment of the suitability of x-ray diffraction for the study of practical residual stress problems. Volume 10 covers a broad spectrum of testing methods in a convenient format, and should be considered for any technical library.

ASM CONFERENCE ON RESIDUAL STRESS MEASUREMENT

The American Society for Metals is planning to hold a conference entitled, “Residual Stress – in Design, Process and Material Selection.” The conference is intended for metallurgist and design engineers, and will address residual stress measurement, the effects of residual stress on fatigue, and processing to control residual stress. Lambda Research has been asked to assist in the planning of the conference to be held in Cincinnati, Ohio, April 27-29, 1987. Information concerning the conference will be available through ASM.

IMPROVED ELECTROPOLISHING CAPABILITY

Lambda Research is pleased to announce an order of magnitude improvement in the rate at which electropolishing can be performed in a variety of materials, allowing stress-free removal of material to far greater depths than was previously practical. Constant current power supplies, developed at Lambda Research and capable of delivering up to 50 amps for preset times, are currently being used for both fine layer removal electropolishing and electrochemical machining. Studies of deep residual stress profiles, such as in induction hardened parts, can now be performed more efficiently, at lower cost, and with improved accuracy.