Diffraction Notes

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PROBLEMS WITH NON-DESTRUCTIVE SURFACE X-RAY DIFFRACTION RESIDUAL STRESS MEASUREMENT

This article relating to the problem of stress variation in the plane of a sample surface is the second in a series of three addressing the difficulties encountered in measurement and interpretation of surface residual stress results. The first article addressed the matter of surface residual stresses which are not representative of the processes which produced them. The final article will address errors caused by the penetration of the x-ray beam in the measurement of the surface stress. A copy of the entire series, to be published as a technical paper through the ASM, can be published by contacting Lambda Technologies.

Part 2:

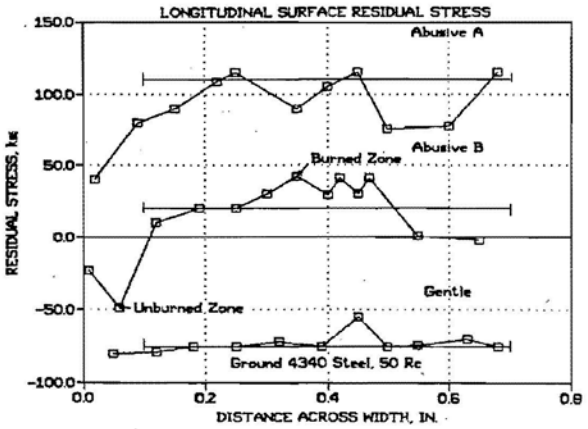
Surface Stress Variation

Many metal removal processes, particularly those involving chip formation such as machining and grinding, can generate pronounced local fluctuations in the surface residual stress. Variation in the depths and magnitude of the deformed layer and the heat input near the surface during chip formation can result in large differences in the resulting surface residual stresses over distances on the order of millimeters.

The apparent surface residual stress measured by x-ray diffraction will then be dependent upon both the size and the positioning of the irradiated area used for measurement. If a sufficiently small irradiated area is used, the assumption of uniform stress within the irradiated area may be satisfied, and the stress variation at the sample surface will be revealed. The surface stress variation can then be so pronounced as to render non-destructive measurement useless for process control.

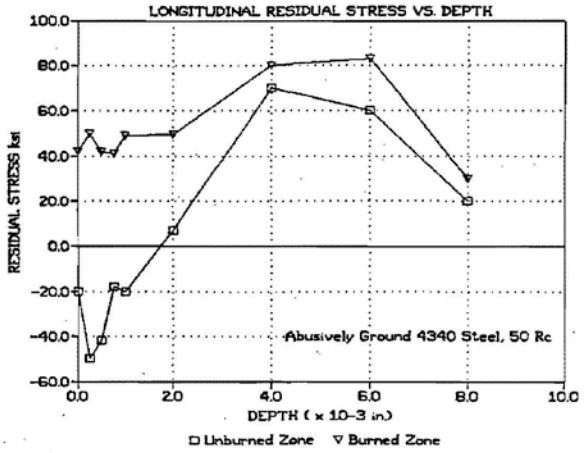
Alternately, the irradiated area may be made large enough to provide a useful average surface stress, but then the assumption of uniform stress in the irradiated area may be violated. The surface stress measured will be the arithmetic average within the diffracting volume, and will depend upon the details of technique used, such as the psi and theta angles, irradiated area, etc.

Figure 1 shows the surface residual stress measured using an irradiated area of 12mm x 0.5 mm across a 19mm wide surface of three ground 4340 steel samples. For the Abusive B Sample, the surface stress varies by nearly 600 MPa (88 ksi) from a region of maximum compression near one edge of the sample to maximum tension in a burned area. The use of a larger irradiated area, plotted as a horizontal line with a length equal to that of the irradiated area, yields the nominal arithmetic mean, as expected.



Variation in Surface Residual Stress Across the Surface of Ground 4340 Steel.[1]

Figure 1

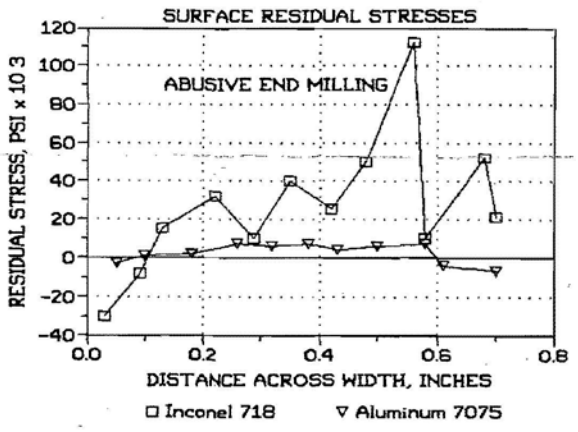


Subsurface Stress Distributions in Adjacent Areas of Ground 4340 Steel Showing Surface Stress Variation and Similar Subsurface Peak Stress[1]

Figure 2

Subsurface measurements at the points of minimum and maximum surface stress shown in Figure 2 reveal comparable subsurface tension at both locations. The near surface layers of ground steels are subject to local phase transformations as well as deformation.

Comparable variations in the surface residual stress are seen in Figure 3 for milled Inconel 718. Work hardening alloys often exhibit local areas of highly worked material at the sample surface.



Surface Stress Variation in End Milling of Inconel 718 and Aluminum[1]

Figure 3

Extreme local variation of the surface stress, frequently encountered on machined and ground samples, may prohibit the use of non-destructive surface x-ray diffraction residual stress measurement for quality control testing. The variability of the local surface stresses and the dependence of the results upon the measurement technique should be investigated before attempting to use surface measurements.

REFERENCES:

[1] Prevey, P.S. and Field, M., Annals of the CIRP, Vol. 24, 1, 1975, p. 498-500.

Quantitative Analysis in Steels

Lambda Research has developed procedures for extraction and gravimetric analysis of carbides present in steels. The procedures are being used to develop techniques for complete phase analysis by x-ray diffraction of steels containing M_7C_3 and $M_{26}C_3$ carbides.

Quantitative Analysis of Hydroxylapatites

Lambda Research is developing software for the quantitative analysis of hydroxylapatites, alpha and beta TCP, and calcium oxide present in synthetic hydroxylapatite. The software employs a combination of background fitting, direct integration, and peak profile fitting techniques for phase separation which can be readily customized to specific mixtures of phases.