Diffraction Notes

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

Because surface measurements are non-destructive, x-ray diffraction is often considered as a method of residual stress measurement for quality control testing. Unfortunately, errors caused by the presence of a subsurface stress gradient and difficulties in interpreting surface results often limit the usefulness of surface data. The magnitude of the potential errors, both in measurement and in interpretation, depends upon the nature of the subsurface residual stress distribution which can only be determined destructively. Although residual stress distributions subject to these problems are commonly encountered in practice, the question of the validity of non-destructive surface results is seldom adequately considered.

There are three primary difficulties associated with both obtaining and interpreting surface x-ray diffraction residual stress results. First, the surface residual stresses present on many samples of practical interest simply are not representative of the processes which produced them. Second, many machining and grinding practices produce variations in the surface residual stresses which are so large that surface results are of little value. Third, many material removal and surface treatment processes produce subsurface stress distributions which vary significantly within the depth of penetration of the x-ray beam, and can cause significant experimental error in the measurement of the surface stress.

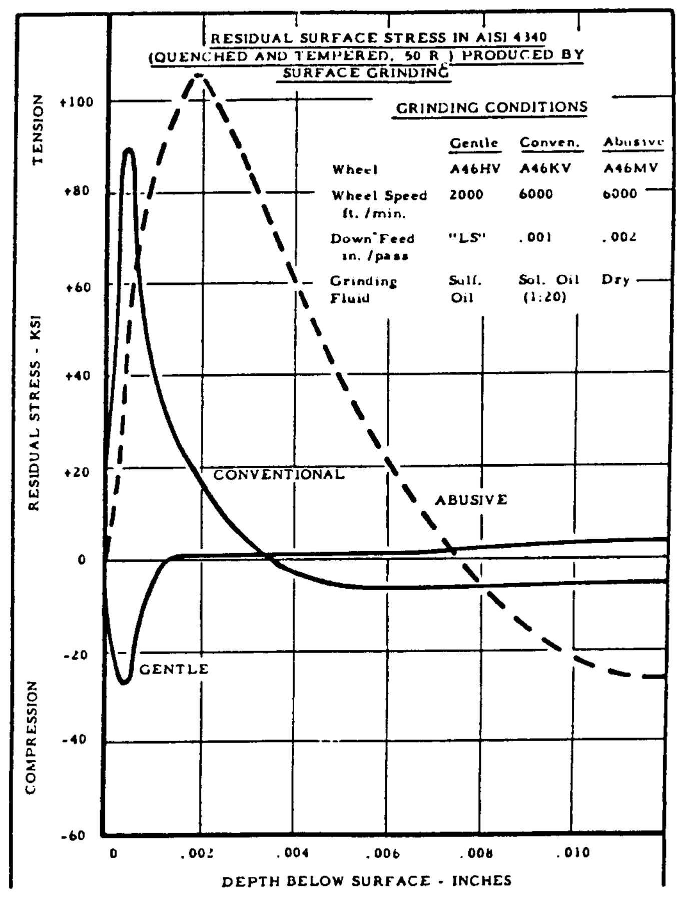
The potential for misinterpretation of surface results obtained by x-ray diffraction is so great that we at Lambda Research feel that a special series of newsletters is warranted. This article is the first of a three-part series addressing each of the difficulties outlined above.

The next article will address the problem of stress variation in the plane of the sample surface. A copy of the entire series, to be published as a technical paper through the ASM, can be obtained by contacting Lambda Research.

I. Surface Stresses May Not Be Representative

Many of the processes of common interest, such as grinding, shot peening, nitriding, etc., can produce nearly identical surface residual stresses for a wide range of processing variables. This feature of the stress distributions may prohibit the use of non-destructive surface residual stress measurements, regardless of measurement accuracy, from being useful for quality control testing.

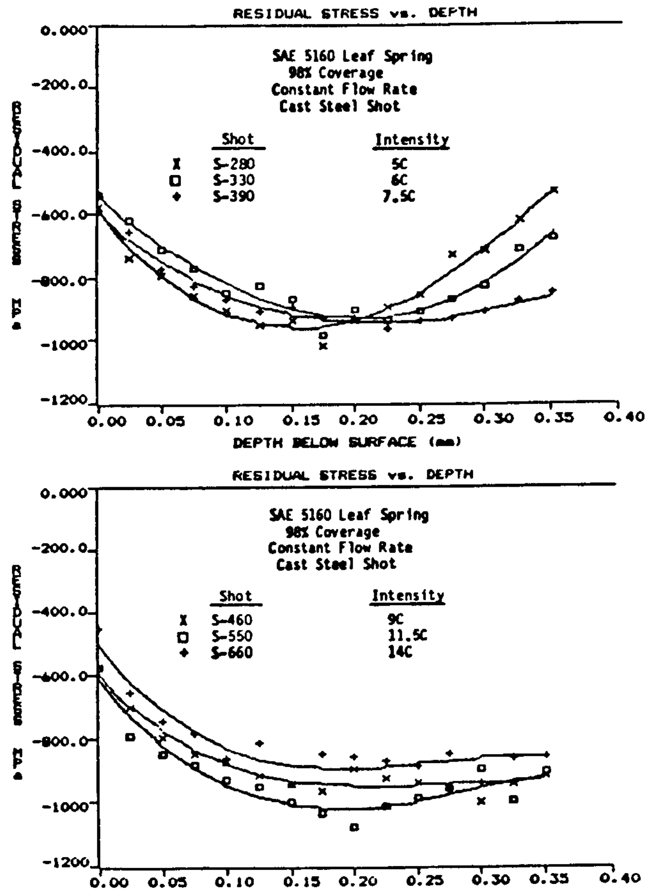
In the case of grinding, where x-ray diffraction is frequently applied, the surface stress may be nearly independent of the grinding parameters. Figure 1 shows three classic representations of gentle, conventional and abusive grinding of 4340 steel measured by a mechanical technique of layer removal and stress relaxation. The near-surface residual stresses range from only 0 to 140 MPa for an extreme range of grinding conditions. Even grinding and shot peening may produce indistinguishable surface stresses as in Figure 4.



Subsurface Stress Distributions Produced by Diverse Grinding Conditions in 4340 Steel[1]

Figure 1

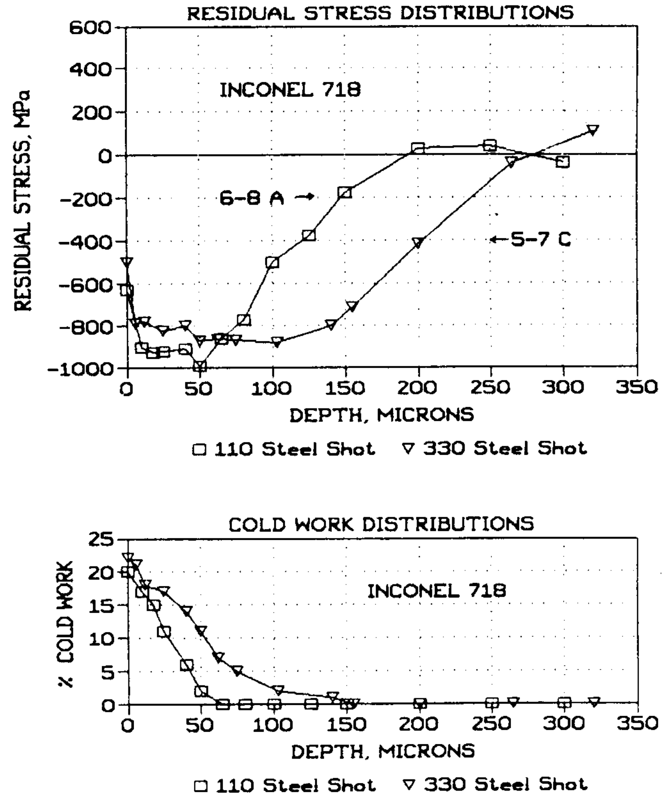
Shot peening also frequently produces nearly identical surface residual stresses for a wide variation in peening parameters, including shot size and Almen intensity. Figure 2 shows results for 5160 steel leaf springs shot peened from a 5C to 14C intensity with shot sizes ranging from S-280 to S-660. The surface residual stresses are virtually identical for all six peening methods, although significant differences are observed in the depth of the peened layer. Figure 3 compares the stress distributions produced by shot peening Inconel 718 to 6-8A and 5-7C intensities.



Subsurface Stress Distributions Produced by Shot Peening SAE 5160 Steel, Showing Similar Surface Values[2]

Figure 2

The results near the surface are, again, virtually identical, but there is a pronounced variation in the depth of the compressive layers. Similar surface results are observed on shot peened 8620 steel gears as well, even though the fatigue life is well correlated to the depth of the peened layer.

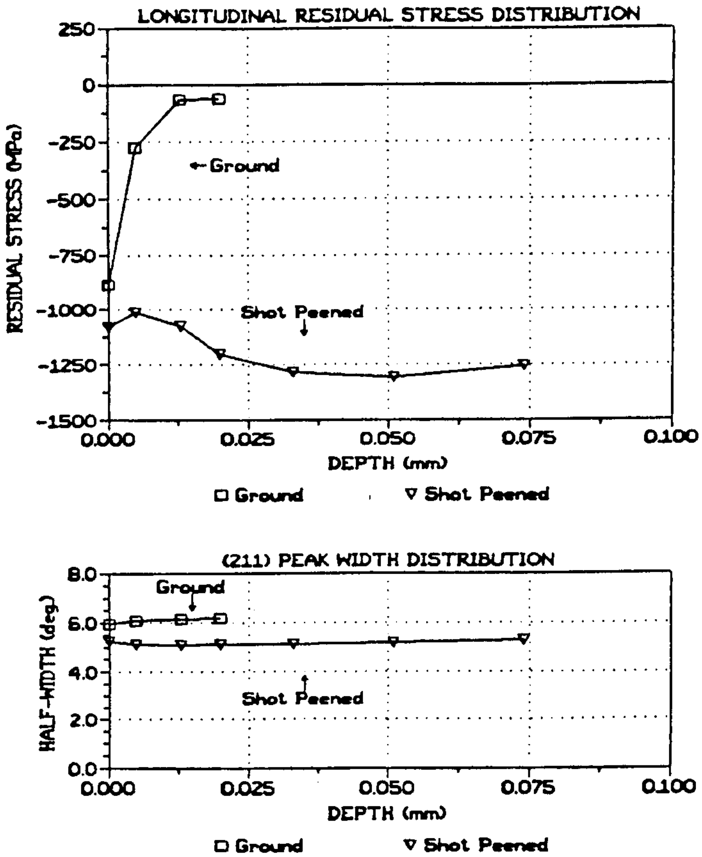


Variation in Depth of the Stress Distributions Produced in Shot Peened Inconel 718, Showing Similar Surface Results

Figure 3

Figure 4 shows comparable surface residual stresses in carburized 8620 steel produced by grinding and shot peening to an 18A intensity. Non-destructive surface residual stress measurement could not be used to distinguish whether the part was in the ground or shot peened condition. A variety of other cold abrasive processes such as sand or grit blasting, wire brushing and even polishing with abrasive paper will produce surface residual stresses indistinguishable to those achieved by shot peening.

A given level of surface residual stress is a necessary but not a sufficient condition to indicate that a critical component may have been correctly processed. The subsurface peak residual stress, rather than the surface stress, has been found to correlate with fatigue life.[1]



Residual Stress and Peak Width Distributions Produced by Shot Peening (18A) and Grinding of Carburized 8620 Steel

Figure 4

The surface residual stress measured non-destructively by x-ray diffraction, or any other means, is frequently inadequate for process control testing and must be used with caution. If surface results must be used, it is always advisable to obtain subsurface results on at least a similar surface to be able to estimate the nature of the subsurface stress distribution.

REFERENCES:

(1) Koster, W.P., et al, "Surface Integrity of Machined Structural Components," US Air Force Materials Laboratory Technical Report No. 70-11, p. 112, 1970.

(2) DeLitizia, A.T., Proceedings of the Second International Conference on Shot Peening, 1984.

PARTNERS IN QUALITY

WHAT OUR ACCREDITATION AND QUALITY ASSURANCE PROGRAM MEAN TO OUR CLIENTS

For a laboratory, accreditation by the American Association for Laboratory Accreditation and membership in the American Council of Independent Laboratories rank as very high achievements of excellence in performance and maintenance of good laboratory practice. At Lambda Research, we have not only achieved accreditation, but have also passed numerous quality audits of our methods and procedures by major clients, including the demanding requirements for the performance of R&D programs for nuclear components and/or systems (per Appendix B of 10CRF50).

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Our accreditation and training program provide you, our client, with a recognized source of competent testing services, adherence to recognized test methods, assurance of internal quality control of our testing methods, permanent retention of all data and calibration records, and traceability of all calibrations.

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Advances in Residual Stress Measurement

Lambda Research has developed proprietary methods of positioning samples repeatedly on the diffractometer to a precision of ± 25 microns (± 0.001 in.). Samples can be removed for electropolishing, measuring, etc., and repositioned to previously unachievable tolerances. The new technology also allows the measurement of the amount of material removed by electropolishing for subsurface measurement to approximately ± 0.25 μm (10^{-5} in.).

The new technology allows precise determination of residual stresses at specified coordinates in complex stress fields, such as near expanded bolt holes, adjacent to fracture surfaces, or near rolled fillets.

ASM CONFERENCE ON PRACTICAL APPLICATIONS OF RESIDUAL STRESS TECHNOLOGY TO BE HELD IN INDIANAPOLIS, MAY 15-17, 1991

The Residual Stress Committee of ASM International's Highway/Off-Highway Vehicle Division has announced their third conference in a series on residual stresses. The scope of this third conference will be the occurrence, measurement and consequences of residual stresses in engineering applications.

Paul S. Prevey, President of Lambda Research, served on the planning committee, and will be presenting two papers, one with Perry W. Mason, Quality Assurance Administrator for Lambda Research.

Information on the conference can be obtained from ASM, Materials Park, Ohio, 216/338-5151.