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X-RAY DIFFRACTION DETERMINATION OF SUBSURFACE RESIDUAL STRESS AND COLD WORK DISTRIBUTIONS PRODUCED BY SHOT PEENING

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Cold working of metals produces extensive dislocation networks within individual grains. The dislocation networks define "crystallites" which are nearly perfectly crystalline subgrains. As the percent cold work increases, the average size of the crystallites is reduced and the average (root mean square) microstrain within the crystallites increases. Both the reduced crystallite size and increased microstrain result in broadening of x-ray diffraction peaks.

Recent developments in Pearson VII function peak profile analysis (1) have allowed the K-alpha 1 diffraction peak width to be separated from the K-alpha doublet with high accuracy. Empirical relationships can be established between the K-alpha 1 diffraction peak width and known amounts of cold work. An empirical curve developed for the nickel base alloy, Rene 95, using specimens deformed in uniaxial tension and compression, and after first grinding or shot peening followed by tensile deformation, is shown in Figure 1. These data and similar results obtained for Inconel 718 demonstrate that the degree of broadening of the (420) diffraction peak for these nickel base alloys is independent of the mode of deformation, and is additive. The percent cold work is taken to be the absolute value of the true plastic strain.

The degree to which the material is cold worked is independent of the macroscopic residual stress. For example, a material may be highly cold worked by uniaxial tension or hydrostatic compression without inducing any macroscopic residual stresses. Many surface treatments such as machining, grinding, or shot peening produce macroscopic residual stress distributions as a result of variation in the amount of tensile or compressive plastic deformation below the sample surface. Using Pearson VII function peak profile analysis, the macroscopic residual stress and percent cold work distributions can be determined simultaneously as functions of depth.

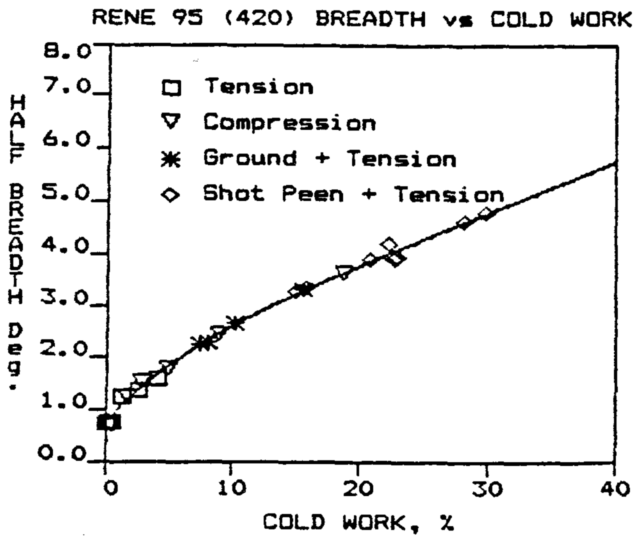

Figure 1

Figure 2 shows examples of macroscopic residual stress and cold work distributions produced near the surface of Inconel 718 samples by abrasive cutting and by moderate (6-8A) and heavy (5-7C) shot peening. The additional information provided by the cold work distribution can be a powerful tool in studying residual stress distributions. A process such as wire brushing may produce compressive surface stresses comparable to shot peening, but with much less cold work. Surface annealing during plasma spray coating or laser treatments can be detected as a reduction in peak width.

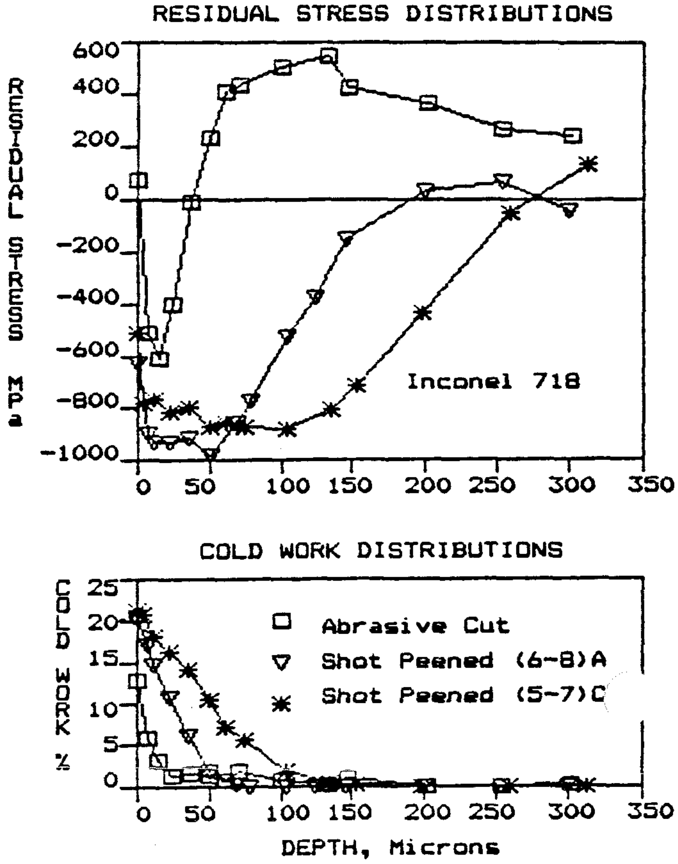

Figure 2

This yield strength of the cold worked surface layers may be altered as a result of the plastic strain induced. The yield strength at the surface of Inconel 600 tubing can be doubled by grinding. (2) The surface layer containing residual stress, cold work, and yield strength gradients may have a pronounced effect on residual stress distributions developed if the material is further plastically deformed, as in the bending of tubing or momentary overloads of shot peened components.

Empirical relationships similar to Figure 2 have been developed for several nickel base alloys to date. A more detailed discussion of the subject of simultaneous determination of residual stress and cold work distributions was presented at the ASM Conference, "Residual Stress — In Design, Process and Materials Selection," held in Cincinnati, Ohio, April, 1987. (3)

(1) P.S. Prevey, "The Use of Pearson VII Distribution Functions in X-Ray Diffraction Residual Stress Measurement," ADV. in X-RAY ANALYSIS, Vol. 29, 1986.

(2) P.S. Prevey, "Surface Residual Stress Distributions in As-Bent Inconel 600 U-Bend and Incoloy 800 90-Degree Bend Tubing Samples, " EPRI Workshop Proceedings, 1980.

(3) P.S. Prevey, "The Measurements of Subsurface Residual Stress and Cold Work Distributions in Nickel Base Alloys," ASM Conference Proceedings, pp. 11-19, 1987.