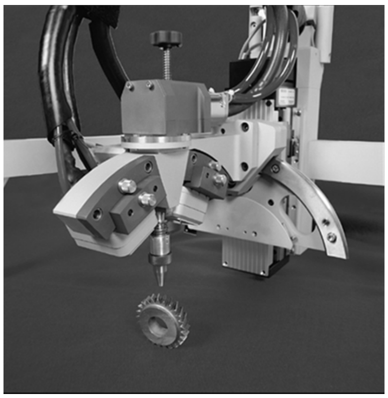
X-Ray Stress Analysis in a Titanium Alloy



The TEC 4000 X-Ray Diffraction System

A residual stress profile near a hole in a titanium alloy, prestrained using a mandrel, was successfully obtained. The residual stresses were determined nondestructively by the multiple tilt x-ray diffraction technique using TEC's portable x-ray diffraction system.

Measurement Parameters Four measurement locations were selected (Figure 1). At each location, measurements were made in two orthogonal directions, denoted as x and y. Measurement location A was as close to the edge of the hole as possible without truncating the collimated beam. Location B was 1/8" from the hole, C was 1/4" from the hole, and D was 4 1/2" from the hole.

For each measurement, five tilt angles (Ψ) were used ranging from -40° to +40°. Copper radiation and a Bragg angle of approximately 142° provided the correct conditions for diffraction of the {213} family of planes. A 2 mm diameter collimator was used. The acquisition time of 150 seconds at Ψ = 0 and power level of 45 kV and 1.9 mA gave good statistical accuracy.

Equipment The TEC 1600 System was used for these measurements. This system employs the $\sin^2\Psi$, or multiple tilt, technique. In this technique, the x-ray beam is directed onto the sample surface at the location of interest. The diffracted radiation is detected by a position sensitive proportional counter (PSPC) detector. The angular position (2θ) of the diffracted beam is used to calculate, via Bragg's law, the distance between parallel planes of atoms (d-spacing) whose normal bisects the angle between the incident and diffracted beams. If stresses exist near the surface of the sample, then the distance between these parallel planes of atoms will be different at different orientations. A series of measurements made at different x-ray beam approach angles (Ψ) are used to fully characterize the d-spacings associated with randomly oriented grains in the sample. The slope of the least-squares fit on a graph of the d-spacing versus $\sin^2\Psi$ is used to calculate the stress.

If the d-spacing versus $\sin^2\Psi$ data are linear, then the assumption of a plane stress state is valid; i.e., there are stresses in the plane of the surface, and no stresses normal to that surface. In some cases, these data are nonlinear. This situation arises when the grain size is large compared to the x-ray beam and/or when the grains exhibit preferred orientation, or texture.

Results The results are listed under Figure 1. Stresses at all measured locations are compressive, and they vary significantly with direction near

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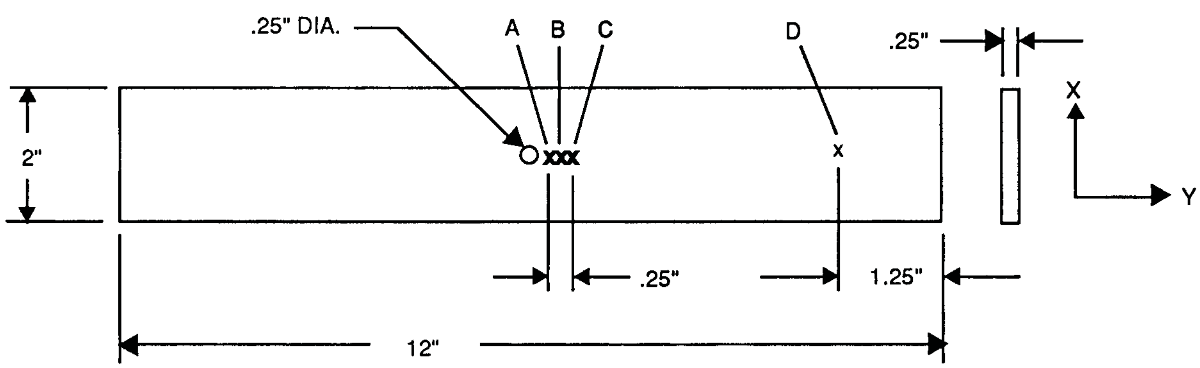
the hole. At location D, 4 1/2" from the hole, the stresses were approximately the same in the x and y direction. In the x direction, the residual stress is -121 ksi at the edge of the hole and decreases in compressive value to -67 ksi 1/4" from the hole. In the y direction, the opposite effect is observed. Stresses are less compressive at the edge of the hole (-54 ksi) and more compressive ¼" from the hole (-95 ksi).

Conclusions It is possible to measure stress gradients nondestructively near prestrained areas in titanium alloy using x-ray diffraction techniques. Stresses in the tangential direction to the hole become less compressive away from the hole, whereas stresses in the radial direction become more compressive away from the hole within the region affected by prestraining. Outside this region, stresses are the same in both x and y directions.

TEC now offers its TEC 4000 X-Ray Diffraction System for reliable stress and retained austenite measurements. Based upon the solid foundation exhibited by the Model 1600 systems, the TEC 4000 offers additional ease of use and versatility.

Figure 1: Measurement Locations



Location	Stress, ksi σ_x	σ_y
A	-120.6 ±5.4	-54.1 ±2.1
B	-99.7 ±1.4	-77.3 ±1.3
C	-67.1 ±1.3	-95.0 ±1.0
D	-62.9 ±3.1	-67.1 ±2.3