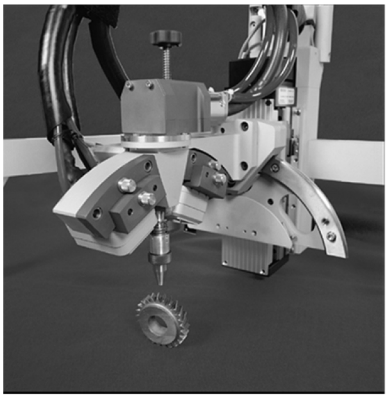
Measurements of Stress by X-Ray Diffraction



The TEC 4000 X-Ray Diffraction System

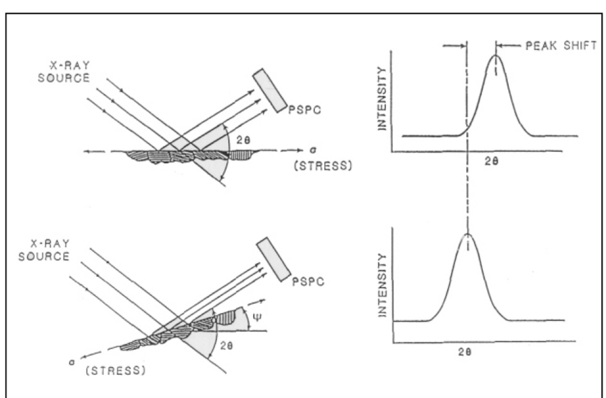
Of the various techniques for measuring residual stresses, the x-ray diffraction method is the most developed and widely used. It is the only technique that is applicable to all crystalline materials, that can measure the absolute stress in the component without the need for a measurement of the sample in the unstressed state, and that is capable of making measurements in a localized region as small as 1 mm in diameter. Because the penetration of the long wavelength x-rays is only a few tens of microns, the TEC 4000 X-Ray Diffraction Systems are used to measure surface stresses.

$$n\lambda = 2d \sin\theta \qquad (1)$$

Stresses are determined by measuring the strain in the atomic lattice and by relating the strains to stresses through the elasticity theory. An incident beam of essentially monochromatic radiation of wavelength λ is diffracted at an angle 2θ which obeys Bragg's Law where n is the order of the reflection and d is the atomic spacing of the selected crystalline lattice planes. The sample surface is at an angle θ to the incident beam, and only grains with atomic planes parallel to the surface diffract. From the 2θ position of the peak, the atomic spacing of the diffracting planes may be determined.

When the sample is tilted an angle ψ the atomic planes that make an angle ψ with respect to the surface now diffract. If there is no stress in the sample, the two diffraction curves superimpose. However, in the presence of stresses, the atomic planes in different orientations are compressed or dilated and a peak shift results. The stress, σ, can be determined from the shift through the relationship where $d\psi$ is the lattice spacing at a tilt Ψ angle and E and ν are Young's modulus and Poisson's

$$\sigma = \frac{E}{1+\nu} \frac{1}{\sin^2\Psi} \frac{(d_\Psi - d_o)}{d_o} \qquad (2)$$



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ratio appropriate to the selected crystallographic planes. The values of $d\psi$ are obtained from Bragg's Law (Equation 1) by careful analysis of the diffraction peak.

Note that it is not necessary to know the d-spacing of the unstressed material. Thus, an accurate and rapid measurement of the location of the diffraction peaks can be used to determine the presence of loading or residual stresses.

With the advanced computer technology and the state-of-the-art detector systems used in the TEC 4000 System, more complex data analyses are possible to account for such effects as stress components normal to the sample surface, and complicating metallurgical variables such as preferred orientation, large grain size, and stress and composition gradients.

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