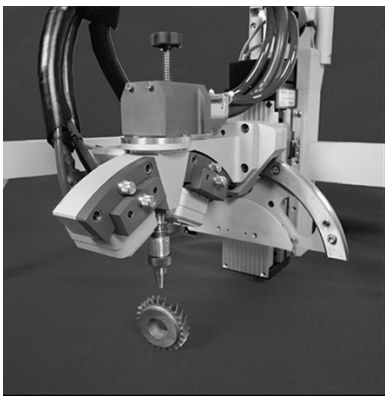
# Improvements in Residual Stress Determination Through the Use of Ψ-Angle Oscillation



*The TEC 4000 X-Ray Diffraction System*

Psi (Ψ)-angle oscillation can be used to improve the accuracy of, or even allow, valid stress measurements on some samples that have preferred orientation (texture) of the grains and/or large grain sizes. Many materials typically exhibit one or both of these phenomena which may result in distortion of the diffraction peak. The distorted diffraction peak, in turn, generally produces a nonlinear d-spacing versus $\sin^2\Psi$ stress analysis plot. The use of Ψ-angle oscillation reduces the nonlinearity of the d-spacing versus $\sin^2\Psi$ plot and thus improves the precision of the stress data.

Most materials exhibit some degree of preferred orientation. Processing techniques, such as rolling, can result in a type of preferred orientation called deformation texture. Some materials, by the very nature of their crystalline structure, will have some preferred orientation. When materials that have preferred orientation are measured for residual stresses via the x-ray diffraction technique, the resulting diffraction peaks will have different integrated intensities and may have distorted diffraction peak profiles.

Heat treating operations used for stress relieving materials often result in large grain sizes. Commonly used materials, such as aluminum alloys and austenitic stainless steels, are notorious for having large grain sizes due to heat treatment parameters specified to produce desired properties. X-ray stress analysis of these materials will also show varying intensities for the diffraction peaks. Moreover, multiple peaks may be seen. Materials that have an ASTM. grain size number of approximately 5 or less are considered large grained materials for stress analysis when the collimated beam is 5 mm in diameter or less.

Stress analysis by x-ray diffraction depends upon accurate determination of the peak position at each Ψ angle. Peak distortion results in less precise stress data. Distorted peaks can be smoothed by employing either sample oscillation or Ψ-angle oscillation. The motor drive on the TEC 4000 X-Ray Diffraction System allows Ψ-angle oscillation to be performed easily, even on parts that are large and bulky, since sample movement is not possible. A Ψ-angle oscillation of about $\pm 2^{\circ}$ is optimum based on experimental results. Figure 1 illustrates the significant improvement in peak profile and d-spacing versus $\sin^2\psi$ plot achievable using ψ-angle oscillation on materials having large grains and/or preferred orientation. This improvement has resulted in more precise stress values.

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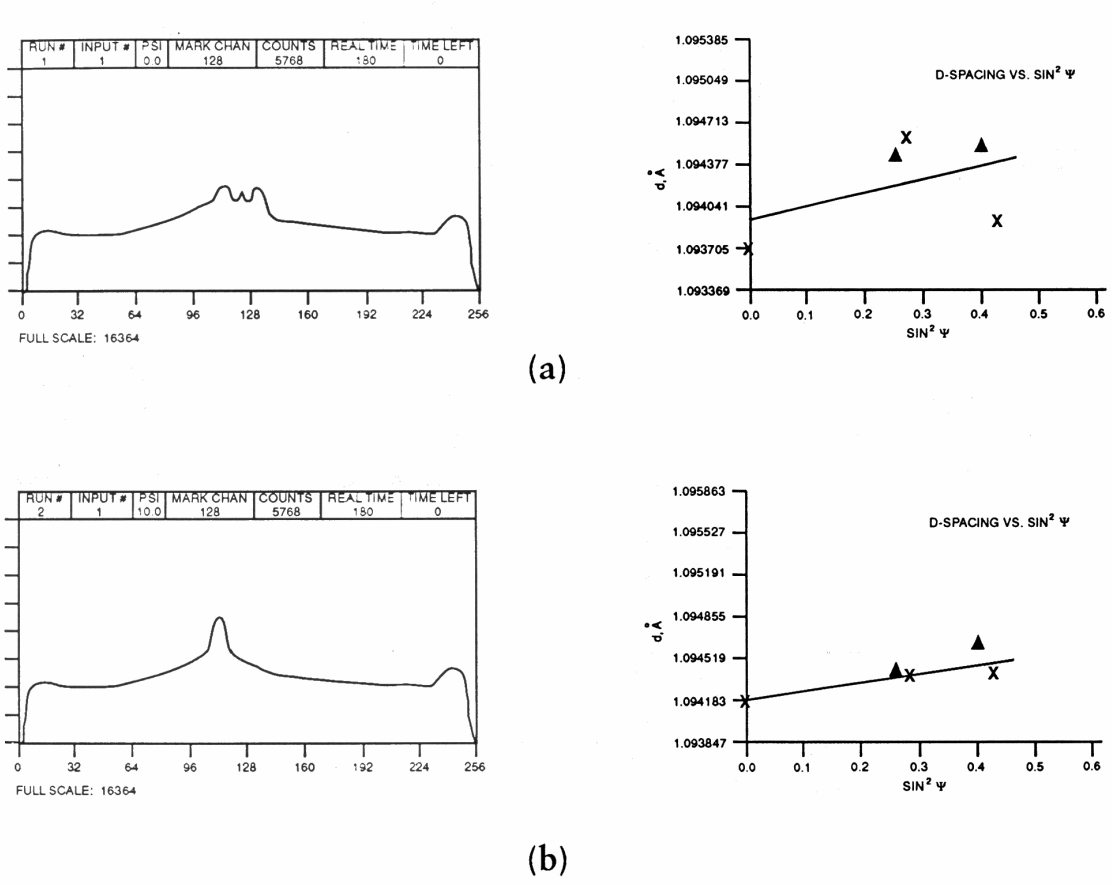


**Figure 1**
Comparison of Diffraction Peaks and d-Spacing vs. $\sin^2\Psi$ Plots on Austenitic Steel (a) without Ψ-Angle Oscillation ($\sigma$ = 21 ksi) and (b) with Ψ-Angle Oscillation ($\sigma$ = 6 ksi).

**Note:**
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