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EVALUATION OF X-RAY DIFFRACTION STRESS INSTRUMENTS USING COS-ALPHA AND SIN^{2}PSI TECHNIQUES IN RELATION TO EXISTING STANDARDS

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ABSTRACT

Residual stress measurement standards and best practices as they apply to x-ray diffraction techniques have evolved in the last few decades to reflect both new developments in data acquisition strategies and analyses, as well as technological advances in the instruments commonly used to collect experimental data. These standards, at a minimum, require the measurement of residual stress on stress-free standard reference materials (SRMs) or powders, and may also require measurements on high-stress proficiency standards or SRMs composed of various materials and alloys. When properly aligned and operated, most x-ray diffraction instruments have the ability to produce accurate results on stress-free powders and SRMs, even when simplified calculation algorithms are employed. In an attempt to further ensure accurate results, users may also be inclined to perform additional measurements on samples under various applied loads to verify that changes in stress values coincide with strain gauge readings under uniaxial tensile loading or four point bend loading. Such loading experiments may also be capable of producing accurate results, seemingly qualifying the instrument suitable for residual stress measurements on any sample. Moreover, many papers have been published to report such findings, and go on to declare that the data collection strategies used by the instrument, the algorithms employed to perform the analyses, and the subsequent calculations are valid. This approach to validation is incomplete and may lead users to erroneous conclusions when triaxial stress fields and/or materials with a heterogeneous microstructure are present. Measurements performed on stress free powders, fine grain proficiency SRMs, and simple loading specimens alone are incapable of revealing flaws in data collection strategies or flaws in analytical models used to calculate residual stress when samples exhibit triaxial stress fields, i.e. have non-zero shear stress components.

To demonstrate the importance of this endeavour, simulation and measurement of residual stress were performed using the Single Exposure Technique, the Multiple Exposure Technique, and the Cos-Alpha Technique on a variety of samples with different triaxial stress states. The results indicate both similarities and differences can be obtained in the results when comparing the various techniques. The similarities and differences observed depend primarily on the type of triaxial stress field present in the component under investigation. Since few of the existing standards and best practices for residual stress measurement are suitable for evaluating instrument capability on samples exhibiting certain triaxial stress states, those lacking should be modified to effectively evaluate instrument capability and the calculations used as a whole. Standards and best practices must consider the techniques used to collect the data, and the stress models used in the calculations so that residual stress measurements on a wide variety of real world components and materials with various microstructural conditions and stress states can be correctly evaluated.