Designation: E915 – 21

Standard Practice for Verifying the Alignment of X-Ray Diffraction Instruments for Residual Stress Measurement[1]

This standard is issued under the fixed designation E915; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes the procedure for verifying the alignment of X-ray diffraction instruments used for residual stress measurements.

1.2 This practice further describes the use of iron powder for fabrication of a stress-free test specimen to be used to quantify the systematic error that can occur in residual stress measurement of ferritic or martensitic steels. This practice is easily adapted to other alloys and ceramics by the use of a powder having a similar diffraction angle to the material to be measured.

1.3 This practice is applicable to all X-ray diffraction instruments that measure diffracted X-rays from the crystal structure of a polycrystalline specimen. It is applicable to the acceptable multiple exposure techniques of residual stress measurement as defined in Test Method E2860. Through measurement of a high-angle back-reflection set of planes, these techniques are used to derive the interatomic spacing (d-spacing) and the crystallographic strain, and then calculate residual stress in which the θ, 2θ, and ψ rotation axes can be made to coincide (see Fig. 1).

1.4 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E6 Terminology Relating to Methods of Mechanical Testing

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E1426 Test Method for Determining the X-Ray Elastic Constants for Use in the Measurement of Residual Stress Using X-Ray Diffraction Techniques

E2860 Test Method for Residual Stress Measurement by X-Ray Diffraction for Bearing Steels

3. Terminology

3.1 The definitions of calibration and verification that appear in Terminology E6 apply to this practice.

3.1.1 In addition, the following common terms from Terminology E6 are defined:

3.1.2 *error, n*—for a measurement or reading, the amount it deviates from a known or reference value represented by a measurement standard.

3.1.2.1 *Discussion*—Mathematically, the error is calculated by subtracting the accepted value from the measurement or reading.

3.1.3 *residual stress [FL^{-2}], n*—stress in a body that is at rest and in equilibrium and at uniform temperature in the absence of external and mass forces.

3.2 The terms accuracy, bias, and precision are used as defined in Practice E177.

4. Significance and Use

4.1 This practice provides a means of verifying the alignment of an X-ray diffraction instrument so as to quantify and minimize systematic experimental error in residual stress measurements. This practice is suitable for application to

[1] This practice is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.13 on Residual Stress Measurement.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

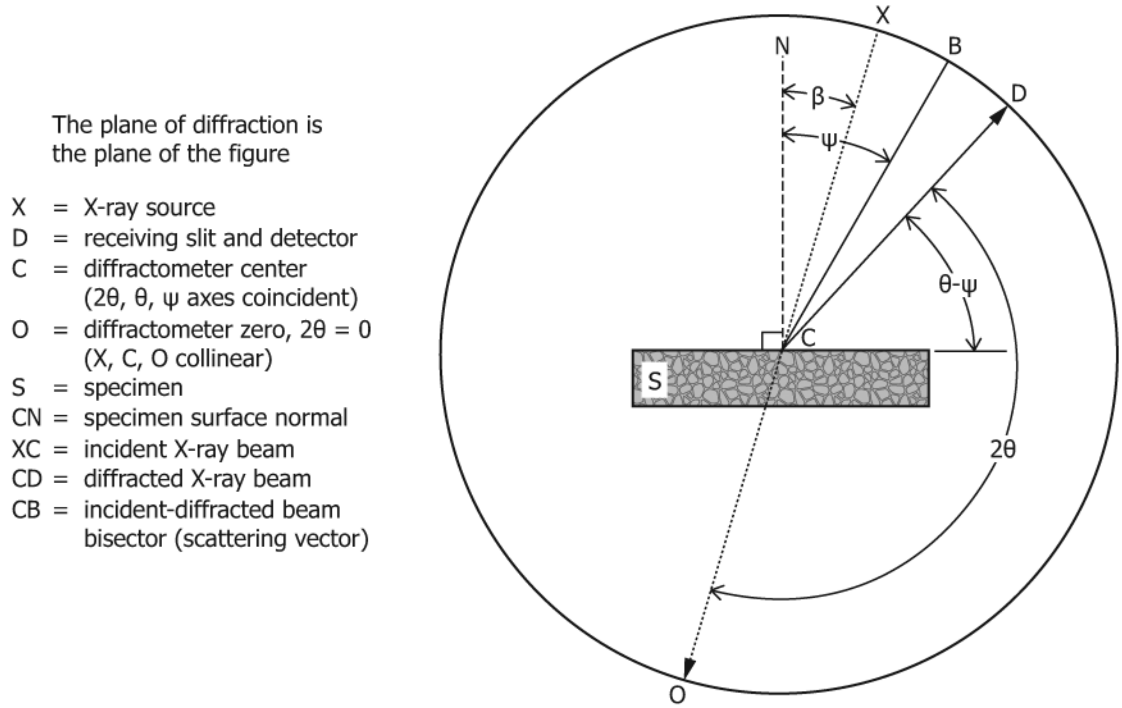

FIG. 1 X-Ray Diffraction Residual Stress Measurement Geometry and Angles Defined

conventional X-ray diffraction instruments or to X-ray diffraction residual stress measurement instruments of either the diverging or parallel beam types[3,4]

4.2 Application of this practice requires the use of a flat stress-free specimen that diffracts X-rays within the angular range of the diffraction peak to be used for subsequent residual stress measurements. The specimen shall have sufficiently small coherent domains or grains, be quasi-homogeneous, quasi-isotropic, and be of sufficient thickness such that incident X-rays interact with and diffract from an adequate number of individual coherent domains or grains such that a near-random grain orientation distribution is sampled. The crystals shall provide intense diffraction at all tilt angles ψ that will be employed.

NOTE 1—A major bias in crystal structure orientation is undesirable, but complete freedom from preferred orientation in the stress-free specimen is not critical in the application of the technique.

5. Procedure

5.1 *Instrument Alignment:*

5.1.1 The X-ray diffraction instrument shall be aligned in accordance with the instructions supplied by the instrument manufacturer. For variable or fixed θ, 2θ, and ψ axes (see Fig. 1), this alignment shall achieve the following:

5.1.1.1 The θ, 2θ, and ψ axes shall coincide at the diffraction center in Fig. 1.

5.1.1.2 The incident X-ray beam shall be centered on the ψ and 2θ axes within a chosen focal distance range. This focal distance range shall conform to the desired error and precision tolerances (see Section 6).

5.1.1.3 The X-ray tube focal spot, the ψ and 2θ axes, and the receiving slit positioned at 2θ = 0° shall lie along a line in the plane of diffraction. Alternatively, for instruments limited to the back-reflection region, the diffraction angle 2θ shall be calibrated in accordance with the instrument manufacturer specifications.

5.1.1.4 The specimen position shall be established, such that the surface of the specimen is positioned at the θ and ψ axes within a chosen focal distance range. This focal distance range shall conform to the desired error and precision tolerances (see Section 6).

5.1.1.5 Values for accuracy and precision of the various ψ angles and displacements may be considered to be met collectively when overall measurement errors and tolerances are within those specified in Section 6.

5.2 *X-Ray Optics:*

5.2.1 Selection of an appropriate X-ray peak should be made at the highest diffraction angle possible, consistent with peak intensity, Bragg reflection multiplicity, and the X-ray wavelength used.

5.2.2 For the purpose of verifying alignment, residual stress measurements on the stress-free specimen shall employ the $K\alpha_1$ diffraction peak at all ψ angles of interest. This is in contrast to residual stress measurements where the Kα characteristic radiation doublet is used to improve accuracy. Alternatively, Kβ peaks may also be used. Although Kβ peaks are generally less intense than Kα peaks they are not doublet peaks, so subsequent analysis on test articles is simplified.

[3] Ahmad, A., Prevéy, P, Ruud, C.O., , eds., *Residual Stress Measurement by X-ray Diffraction*, SAE HS-784, Society of Automotive Engrs., Inc., Warrendale, PA (2003).

[4] "Standard Method for X-Ray Stress Measurement," *Committee on Mechanical Behavior of Materials*, The Society of Materials Science, Japan, (20 April 1973).