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Study of Error Analysis and Sources of Uncertainty in the Measurement of Residual Stresses by the X-Ray Diffraction

Authors : E. T. Carvalho Filho, J. T. N. Medeiros, L. G. Martinez

Abstract : Residual stresses are self equilibrating in a rigid body that acts on the microstructure of the material without application of an external load. They are elastic stresses and can be induced by mechanical, thermal and chemical processes causing a deformation gradient in the crystal lattice favoring premature failure in mechanicals components. The search for measurements with good reliability has been of great importance for the manufacturing industries. Several methods are able to quantify these stresses according to physical principles and the response of the mechanical behavior of the material. The diffraction X-ray technique is one of the most sensitive techniques for small variations of the crystalline lattice since the X-ray beam interacts with the interplanar distance. Being very sensitive technique is also susceptible to variations in measurements requiring a study of the factors that influence the final result of the measurement. Instrumental, operational factors, form deviations of the samples and geometry of analyzes are some variables that need to be considered and analyzed in order for the true measurement. The aim of this work is to analyze the sources of errors inherent to the residual stress measurement process by X-ray diffraction technique making an interlaboratory comparison to verify the reproducibility of the measurements. In this work, two specimens were machined, differing from each other by the surface finishing: grinding and polishing. Additionally, iron powder with particle size less than 45 μm was selected in order to be a reference (as recommended by ASTM E915 standard) for the tests. To verify the deviations caused by the equipment, those specimens were positioned and with the same analysis condition, seven measurements were carried out at 11Ψ tilts. To verify sample positioning errors, seven measurements were performed by positioning the sample at each measurement. To check geometry errors, measurements were repeated for the geometry and Bragg Brentano parallel beams. In order to verify the reproducibility of the method, the measurements were performed in two different laboratories and equipments. The results were statistically worked out and the quantification of the errors.

Keywords : residual stress, x-ray diffraction, repeatability, reproducibility, error analysis
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