APPLICATION OF A POSITION SENSITIVE SCINTILLATION DETECTOR TO NONDESTRUCTIVE X-RAY DIFFRACTION CHARACTERIZATION OF METALLIC COMPONENTS

Clay Olaf Ruud

Materials Research Laboratory
The Pennsylvania State University
University Park, Pennsylvania

ABSTRACT

A unique instrument for the x-ray diffraction (XRD) characterization of crystalline materials has been developed and is being applied to a number of studies of metallic components. The instrument is based upon a unique position sensitive scintillation detector (PSSD) for x-rays. The methodology for the application of this instrument to the single-exposure technique (SET) of x-ray stress measurement is described. A number of applications of the device to residual stress measurement and qualitative cold work damage assessment in metallic components are discussed and data from these applications presented. Also, the application of the PSSD instrument to texture measurement is described.

INTRODUCTION

X-Ray Diffraction (XRD) characterization of polycrystalline materials relies upon the ability of this method to accurately measure the interatomic planar spacing of the material under study. In the most elementary form the Bragg equation

\[ n\lambda = 2d \sin \theta \]

describes the relationship between the various parameters, where \( n \) is normally unity, \( \lambda \) is the wavelength of the interrogating radiation, \( d \) is the interatomic spacing, and \( \theta \) is the Bragg angle. Characterization in XRD is usually accomplished by selecting a monochromatic x-radiation and measuring \( \theta \) and thus obtaining the interplanar spacing, \( d \). The mean value of \( d \) may be used for the
measurement of elastic strain, and therefore applied and residual stress [1,2]; preferred orientation, or texture [2,3]; phase identification [4]; and quantitative phase analysis, including retained austenite determination [3,4]. The distribution of the d values about the mean is indicative of cold work damage [2]; crystallographic lattice parameter variation, including elemental variation [4]; and particle size [4].

In most cases each of the aforementioned characteristics may be measured independently, although in certain instances the isolation of a single property may require rather sophisticated analysis [5].

BACKGROUND

Extensive industrial application of XRD as a characterization tool has been realized with respect to phase identification and phase analysis, as is manifest in the thousands of computer-automated x-ray diffractometers which are being used in routine analysis. However, the application of XRD to residual stress, texture, cold-work damage, and in some cases phase analysis has been greatly hampered by restrictions on specimen size and shape dictated by the instrumentation available.

There are several basic types of instrumentation used for material analyses and characterization by XRD, but the most popular by far is the Bragg-Brentano para-focussing goniometer. Several manufacturers in the free world are marketing diffractometers based upon this design which has remained fundamentally the same for several decades. Essentially this XRPD diffractometer consists of a mechanical turntable capable of positioning a powder specimen at various known θ angles with respect to an incident x-ray beam, and a detector scanning at twice the angle that the specimen is rotating. The scanning is accomplished in such a way that the detector is in a position to intercept the diffracted x-ray beam whenever the Bragg condition is met. There are several excellent descriptions of this device, including Barrett [3], Cullity [2], and Klug and Alexander [4]. This scanning detector device has been the workhorse of XRD analysis since the late 1940's and presently the most modern versions are computer automated.

In the early 1970's however the technology for x-ray detectors which did not have to be moved, i.e., mechanically scanned, to detect angle of Bragg x-ray diffraction evolved to produce reliable devices with sufficient spatial resolution to be suitable for application to XRPD. These so-called position sensitive detectors (PSD) found many applications where they were substituted for the x-ray detector normally used on the scanning diffractometers [6]. By and large these detectors have been based upon the same principle.