Aerospace
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VEQTER

Residual Stress

VEQTER is an engineering company providing excellence in the measurement, analysis and management of residual stresses. We are world leaders in our field and offer expertise on any aspect related to residual stresses in engineering components and structures.

Neutron Diffraction Technique

The Neutron Diffraction (ND) technique measures residual stresses deep within a material by detecting the diffractions of an incident neutron beam.

Like the other diffraction techniques, i.e. laboratory X-ray and Synchrotron Diffraction, the diffracted beam of neutrons behaves according to Bragg's Law enabling the detection of changes in atomic lattice spacing due to stress. The relative changes in spacing are then calibrated using a stress-free material sample (i.e. d_0 sample) to calculate absolute stress values. The advantage of using neutrons compared to x-rays is their deeper penetration into engineering materials (i.e. centimetres rather than millimetres for synchrotron x-rays or µm for laboratory x-rays).

There are two main types of Neutron Diffraction technique, monochromatic 2θ Strain Scanning and Time of Flight; the use of which type depends upon the diffraction instrument's neutron source.

To find out how VEQTER can help you please contact us on +44 (0) 117 992 7970 or using experts@veqter.co.uk

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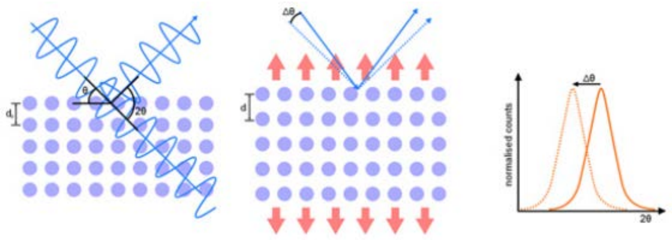
Residual Stress Experts

Monochromatic 2θ Strain Scanning:

This technique is commonly found at a reactor source and is based on a monochromatic (i.e. single wavelength) neutron beam. It measures changes in the peak diffraction angle of a single diffraction peak, 2θ, relating to a particular lattice spacing, d, due to residual stresses.



Schematic showing the incident and diffracted neutron beam with changing angle 2θ

Differentiating Bragg's law ($n\lambda = 2d_{hkl}sin\theta$) for constant wavelength, λ gives:

$$\Delta\theta_{hkl} = -(\Delta d/d_0)tan\theta_0$$

Where $\Delta\theta$ is the peak shift, Δd is the change in lattice spacing, d_0 is the lattice spacing of a stress-free sample and $2\theta_0$ is the corresponding angular position of diffraction peak for the stress-free sample.

The strain in the *hkl* set of planes can be calculated as:

$$\varepsilon^i_{hkl} = \frac{\Delta d_{hkl}}{d^0_{hkl}} = -\Delta\theta_{hkl}cot\theta^0_{hkl}$$

Time of Flight:

A spallation source produces neutron beams of varying wavelengths/energies in pulses at time t_0. The neutron beams have different velocities, with energetic neutrons travelling the fastest, and can hence be discriminated by their time of flight (or arrival) at the detector. Since all wavelengths are present, the detectors can be placed at 90° to ensure a cuboidal gauge volume, unlike Synchrotron Diffraction. By monitoring the incident/diffracted wavelength at constant Bragg angle, θ, the lattice spacing can be determined. Differentiating Bragg's law for constant θ:

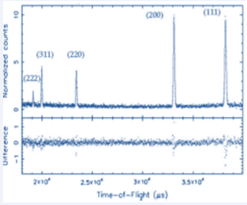
$$\Delta\lambda = \frac{\Delta d}{d_0}\lambda_0$$

Where $\Delta\lambda$ is the change in wavelength and λ_0 is the wavelength corresponding to the stress-free sample.

The strain can be calculated as:

$$\varepsilon^i_{hkl} = \frac{\Delta d_{hkl}}{d^0_{hkl}} = \frac{\Delta\lambda}{\lambda_0} = \frac{\Delta t}{t_0}$$

Complete or partial diffraction spectrums can be obtained from each measurement point. The diffraction profiles are then analysed using multiple peak fitting (e.g. Pawley or Rietveld refinements) to provide lattice parameters α and α_0 for the stressed and stress-free material.



ND facilities worldwide:

Technique Specifications:

- "Non-destructive" technique, although d_0 samples may need to be extracted or beam access windows cut;
- Good penetration depths – up to 60mm in steel, 100mm in aluminium (total beam path lengths)
- Small gauge volume 1 to 10mm^3
- Tri-axial residual stress measurements (i.e. σ_{xx}, σ_{yy} and σ_{zz}), including stress gradients;
- High magnitude residual stresses are measured accurately;
- Complex shapes can be measured, although beam access windows may need to be cut;;
- Indifferent to surface finish;
- Nominal accuracy: 10MPa – Aluminium, 30MPa – Steel, 15MPa – Titanium;
- Macro and micro residual stresses measured
- Laboratory based measurements at specialist facilities
- Only applicable to crystalline materials
- Accuracy seriously affected by grain size and texture
- Specimen size restricted (volume and weight)
- Very long lead times before measurement unless beam time paid for commercially