Fine residual stress distribution measurement of steel materials by the SOI pixel detector with synchrotron X-rays

AKEK, Kanazawa Univ.

Introduction

Residual Stress measurement (Cos a method)

Debye-Ring formed by diffraction of X-ray beams on the surface (~10μm) of polycrystalline metal.

Debye-ring’s deformation is related to the status of residual stress on crystal structure. This deformation is sensitive to stress of tilt direction a. Variation rate of grating interval (Δd = strain by residual stress) can be calculated from Debye-ring’s deformation. And Δd can converted to amount of residual stress by Hooke’s law.

Residual stress can be evaluate from Debye-ring’s deformation without destruction.

• Definition of stress amount’s positive and negative : Tensile side is positive, Compressive side is negative.

SOI Pixel detector in new measurement system

We are now developing the residual stress measurement system based on the cos a method using the two-dimensional detector. The silicon on insulator (SOI) pixel detector, named INTPIX4, was implemented as this system’s two-dimensional detector. (left photo is Wire-bonding (WB) implementation type board.)

INTPIX4 has 14.1mm × 8.7mm sensitive area/chip which consists of Column 832 × Row 512 of 17μm × 17μm size pixels.

Experimental results

2D mapping

Procedure
1. Measure Debye-ring of Fe Powder specimen (Sinto).
2. Measure Debye-ring of Residual stress standard specimen (Sinto).
3. Calculate Injection beam center from Debye-ring of Fe Powder specimen.
4. Calculate distribution of amount of residual stress on Residual stress standard specimen from Debye-ring of each point.

• 384.0 MPa specimen was measured twice for reproducibility check.

Photo of specimens

Residual stress standard

Fe Powder

Measurement points

2.5 mm step, 3 × 3 points including center point. No.5 is center of specimen.

Setup of Residual stress measurement

Setup’s photo (from X-ray beam downstream side)

Sample

Material : Steel

Diffraction plane : (h, k, l) = (2, 1, 1)

• Sinto (新東工業) residual stress standard specimen for X-ray measurement (3 types)

Nominal value (avg. of 5 tests of center point) : -384.0 MPa, -785.5 MPa, -1517.7 MPa

*Results of -384.0 MPa were shown in this Poster.

• Sinto Fe Powder specimen for beam center calibration

Conclusion

Conclusion

• X-ray Residual Stress measurement (Cos a method) is non-destructive residual stress evaluation technique using Debye-ring’s deformation.
• We tried to measure residual stress by synchrotron’s monochromatic X-ray beam (5.415keV) at Photon Factory BL-14A.
• Synchrotron X-ray beam’s data has larger error caused by lack of intensity, however, the experimental results are not conflicting to existing result measured by Laboratory’s X-ray tube (Cr Kα)

For the future

Check and fix (if necessary) about :
• Lack of intensity
• Analysis algorithm
• Setup’s instability
• Optics and detector’s true detection efficiency
• Energy spectrum of Lab’s X-ray tube