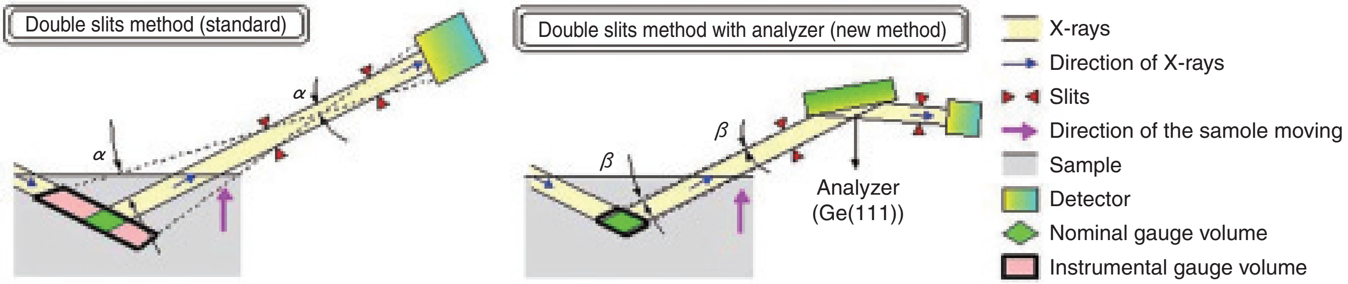
4-10 Residual Stress Measurement of Internal Materials Using Synchrotron Radiation

－Stress Analysis Technique with a New Strain Scanning Method－



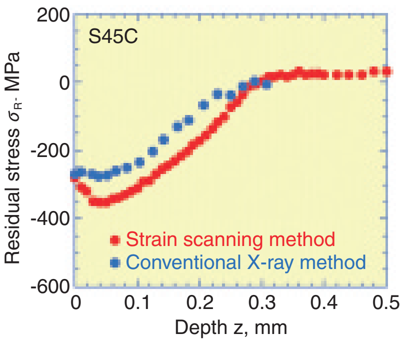


Fig.4-22 (Upper)　Optics of strain scanning method

In the strain scanning method, the distribution of the strain or stress beneath the surface can be determined by scanning the gauge volume in the depth direction of the specimen. In the standard method, the instrumental gauge volume is much larger than the nominal gauge volume and the measurement error is large. On the other hand, in the new method, the instrumental gauge volume is equal to the nominal gauge volume and the measurement error is much less.

Fig.4-23 (Left)　Distribution of residual stress measured by new type strain scanning method

The red circles indicate the in-plane residual stress at each depth of S45C (steel with 0.45% carbon) which was shot-peened to introduce a compressive residual stress in the surface layer. The blue circles indicate the out-of-plane residual stress obtained in our previous study, where the surface layer of the shot-peened specimen was removed successively by electropolishing and the stress measurement by the $\sin^2\psi$ method using Cr-Kα radiation was repeated. The strain scanning method is a useful alternative to the conventional X-ray method because the stress distribution below the surface is obtained non-invasively and in a short time with the same accuracy.

To guarantee the reliability of structural component service, a non-destructive method is required to determine a precise distribution of the residual stress in materials. A strain scanning method based on X-ray diffraction method using synchrotron radiation is used to measure the strain and the stress. We improved this method, attempting to measure the residual stress of a local internal area of a material with high precision.

In order to measure the residual stress of a local area with the high precision, X-rays with high brilliance, high flux and high energy, and optics with high resolution are necessary. An original monochromator for high energy X-rays and an undulator in which permanent magnets are arranged in the straight section of the accelerator so that their south pole and the north pole alternate vertically were installed to obtain such X-rays. To achieve high resolution in the optics, a single crystal called an analyzer was installed (Fig.4-22). The analyzer is suited to measure with high resolution because it reflects monochromatized X-rays over a very small angle range, but the problem occurs that the X-ray intensity diffracted by the analyzer greatly decreases. Our proposed method enables a high space-resolution evaluation of the stress distribution which takes a few hours, whereas the conventional X-ray method takes several days (Fig.4-23).

The strain scanning method developed in this study can determine the stress distribution with the spacial resolution of several hundreds μm^2 around a crack in internal material by using high energy synchrotron radiation X-rays. Furthermore in - situ stress measurement under high temperature or high pressure can be carried out because the measurement time of the strain scanning method is very short.

This newly developed method can be applied to various problems of concern to JAEA, such as stress corrosion cracking, development of materials for nuclear power generating plants, and the container for mercury target of “J -PARC”. Furthermore, in the industry - academia - government collaboration, this method is applicable to research vital to the energy problem, for example, thermal barrier coating for a high efficiency jet turbine and solid oxide fuel cells.

Reference

Shobu, T. et al., High Space-resolutive Evaluation of Subsurface Stress Distribution by Strain Scanning Method with Analyzer Using High-energy Synchrotron X-rays, JSME International Journal Series A, vol.49, no.3, 2006, p. 376-381.