THERMAL STRESS MEASUREMENT OF MMC BY $\sin^2\psi$ METHOD

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1. Introduction

The final purpose of this study is to thermal stresses measurement in the W/Ti fibre reinforcement composite [1] using $\sin^2\psi$ method. In this report, the possibility of the neutron stress measurement by the $\sin^2\psi$ method was confirmed using the low carbon steel sample. This is preparation stage of the final purpose.

$\sin^2\psi$ method generally used in X-ray stress measurement and the plane stress state can be defined because the penetration depth of X-rays is sufficiently shallow. However, in the case of neutron stress measurement, the stress state is generally triaxial condition and the plane stress state does not hold. Therefore, in this study, this problem is avoided by applying a uniaxial tensile load to the sample.

From the calculation of elasticity theory, the basic equation of $\sin^2\psi$ method becomes

$$\varepsilon_{\phi\psi} = \frac{1+\nu}{E}(\sigma_{11}-\sigma_{33})\sin^2\psi - \frac{\nu}{E}(\sigma_{11}+\sigma_{22}) + \frac{1}{E}\sigma_{33} \quad . \qquad (1)$$

The stress (σ_{11}-σ_{33}) can be obtained from the slope of the $\sin^2\psi$ diagram, but usually σ_{11} and σ_{33} can not be separated. However, when uniaxial load is applied to the sample in the direction of σ_{11}, condition of $\sigma_{33} = 0$ is holded. As a result, the uniaxial load stress σ_{11} can be obtained from the $\sin^2\psi$ diagram.

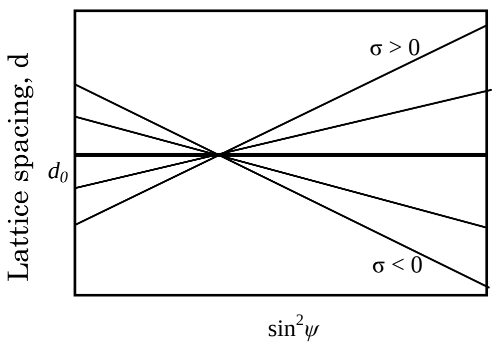

Fig. 1 Schematic diagram of theoretical $\sin^2\psi$ diagram

On the other hand, Fig. 1 shows an outline of the $\sin^2\psi$ diagram in several loads. When the ordinate is the lattice spacing d, the $\sin^2\psi$ diagram shows a straight line rising to the right due to tensile load. Conversely, in the case of a compressive load, a straight line becomes downward slope. Each of these straight lines intersects theoretically at one point, and its value is equal to d_0. Assuming $\sigma_{33} = 0$ and drawing a $\sin^2\psi$ diagram exactly, we can theoretically derive the lattice spacing d_0 in the unstressed state.

2. Experimental method

For neutron measurement, we used a neutron diffractometer No.1 (DN1) installed at Indonesia Atomic Energy Research Institute (BATAN). An Euler cradle (spindle goniometer) was placed on the sample stage of DN1, and a small tensile tester was mounted. This small tensile machine was designed and manufactured newly at Kobe City College of Technology in Japan, so that it could be set in BATAN's equipment. Fig. 2 shows an outline of the small tensile machine manufactured this time. Annealed steel samples were used for the tensile test. The heat treatment method was oil quenching of from 900°C for the steel material SS400 . After holding at 750°C for 1 hour, the sample was cooled in the furnace. The thickness of the sample was 6 mm, and the width of the parallel part was 3 mm. The applied stress was calculated from the strain value of the strain gage pasted on the sample. The small tensile machine was set on the Euler cradle in Fig.3. The sample setting is carefully installed using a laser displacement meter and a laser liner.

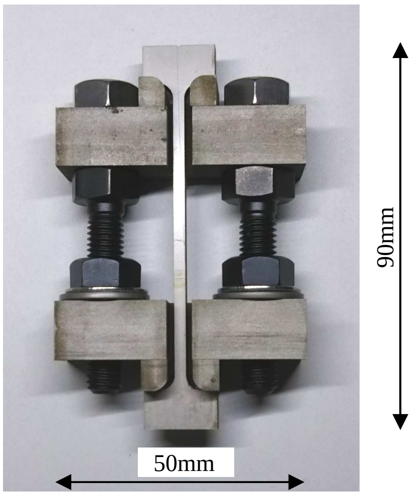

Fig. 2 Photographs of the tensile testing machine and sample.

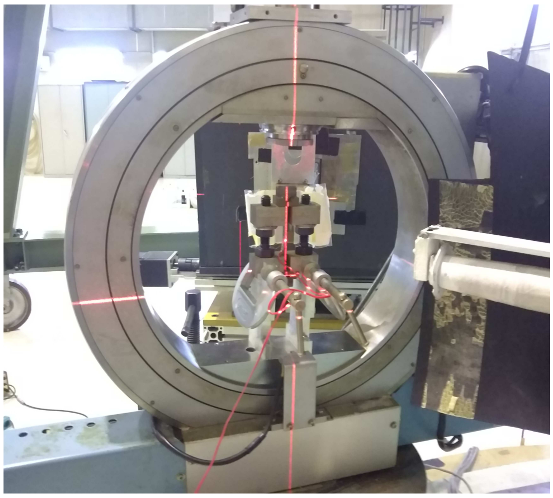

Fig. 3 Photograph of sample setting in the neutron diffractometer and the Euler cradle.

3 Measurement result and discussion

Fig. 4 shows the results of measurement on the 211 diffraction plane in the $\sin^2\psi$ diagram. In the figure, the unloaded results are connected by lines for reference. Originally, in the stress free state, the $\sin^2\psi$ diagram should be a horizontal straight line. However, the measurement results are curved. The reason for such curvature is considered to be as follows. The optical system slit of DN1 controls the divergence of the neutron beam in the horizontal direction. However, the vertical divergence is not controlled. Therefore, it can be assumed that the neutron beam irradiated to the sample has the intensity distribution in the vertical direction. As a result, the wavelength and intensity of the neutron beam change when the neutron beam irradiation area protrudes from the measurement part of the sample with the change of the ψ angle. From this reason, it is considered that the $\sin^2\psi$ diagram did not become a horizontal straight line. We are currently preparing new experiments to investigate these causes in detail. Fig. 5 shows the result of regression lines of the $\sin^2\psi$ diagram. From the change of the regression lines, the slope of the $\sin^2\psi$ diagram increases with the increase of the applied stress. Furthermore, the approximate curve shows the tendency to intersect at one point. From this result, it is confirmed that the $\sin^2\psi$ method can be evaluated if the correction is added.

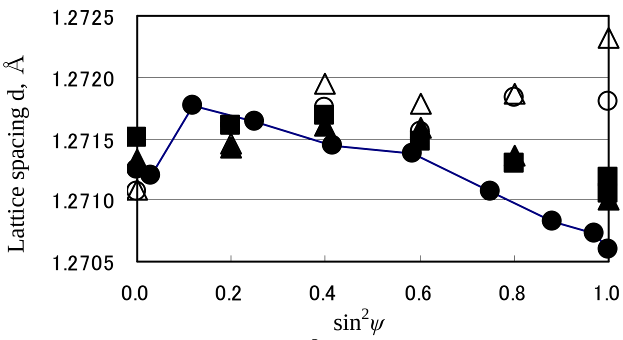

Fig. 4 Results of $\sin^2\psi$ diagram of 211 plane.

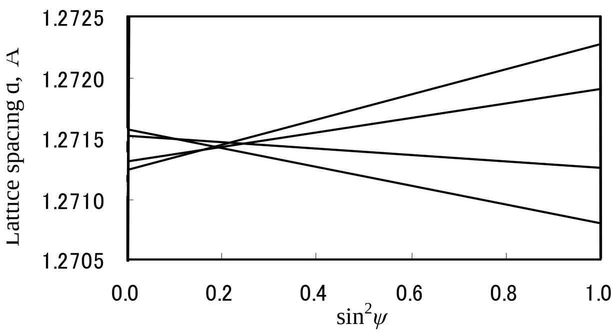

Fig. 5 Results of $\sin^2\psi$ diagram explained by regression lines.

REFERENCES

[1] MASAYUKI Nishida, MASASHI Haneoka, TATSUYA Matsue, TIAN Jing and TAKAO Hanabusa: Materials Science Forum Vols. 768-769 (2014) pp 335-342.