（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。）

MLF Experimental Report	提出日 Date of Report August 30th, 2012
課題番号 Project No. 2012A0043 実験課題名 Title of experiment Neutron attenuation effect on strain measurement using neutron diffraction 実験責任者名 Name of principal investigator Hiroshi Suzuki 所属 Affiliation Japan Atomic Energy Agency	装置責任者 Name of responsible person Kazuya Aizawa, Stefanus Harjo 装置名 Name of Instrument/（BL No.） TAKUMI/ BL19 実施日 Date of Experiment April 10th – April 13th, 2012 May 19th – May 20th, 2012 May 24th – May 25th, 2012

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

- Annealed steel plate (JIS-SM400A*) 100mm x 100mm x 50mm
- Plastically bent steel plate (JIS-SM400A*) 100mm x 100mm x 50mm
- Annealed steel stick (JIS-SM400A*) 1mm x 1mm x 50mm

*JIS-SM400A: Fe, 0.2C, 0.23Si, 0.87Mn, 0.018P, 0.005S

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

The neutron diffraction technique using the time-of-flight method can measure the average residual strain in a gauge volume which is defined with an incident beam slit and radial collimators. In general, most representative position in a gauge volume is a neutron weighted center of gravity (ncog) in the gauge volume, which takes into account variations in intensity due to attenuation or absence of sample materials. Position difference between an ncog and a geometrical center of gauge volume (gcog) can cause an apparent peak shift, resulting in a pseudo-strain.

Residual strain distributions of a plastically bent steel plate were measured with different gauge volumes defined by 2 mm radial collimators and incident beam slits with apertures of 2 mm, 8 mm and 14mm widths (*w*1) and 25 mm height. Figure 1 shows comparison of normal strain distributions measured using different gauge volumes superimposed with the strain distribution previously measured with an angular dispersive method. The normal strain distribution apparently moved towards the through-thickness center with an increase of the gauge volume since the residual strain in the gauge volume was weighted towards the strain at the ncog position due to neutron attenuation effect. In contrast, transverse strain distributions measured in transmission geometry showed similar variation in all gauge volume conditions because the ncog position in any gauge volumes always coincided with the gcog position.

Figure 2 shows normal strain distributions of an annealed steel plate measured with the same measurement condition as those of plastically bent steel plate. Typical partial illumination effect as an increase of pseudo strain was observed near the sample surface. Furthermore, pseudo-strains were also appeared in deeper region even where the gauge volume was perfectly filled in the sample. According to Creek's investigations [1], the pseudo strain measured at k^{th}ch of a detector bank can be predicted by the following equation,

$$\varepsilon_k = \frac{\Delta(L_k \sin\theta_k)}{L_k \sin\theta_k} = \frac{\Delta L_k}{L_k} + \cot\frac{2\theta_k}{2} \cdot \frac{\Delta 2\theta_k}{2}. \qquad (1)$$

Figure 2 also shows pseudo-strain distributions numerically simulated based on Eq. (1) for comparison with measured strain distributions, and it was clearly confirmed that the simulated pseudo-strains were much smaller than measured pseudo-strains. For discussing the reason why such large pseudo-strains were measured, a pseudo-strain mapping was made by scanning a stick type specimen with 1mm square cross-section in a gauge volume. As a result, it was clarified that divergence of the incident neutron beam was very important factor to simulate the pseudo-strain accurately. Furthermore, this result showed energy dependence on the pseudo-strain probably associated with the energy dependence of the neutron divergence in a super-mirror guide tube. Here, we modified Eq. (1) in consideration of a divergence angle, $\Delta\eta$, of an incident neutron beam as follow,

$$\varepsilon_k = \frac{\Delta(L_k \sin\theta_k)}{L_k \sin\theta_k} = \frac{\Delta L_k}{L_k} + \cot\theta_k \cdot \left(\Delta\theta_k - \frac{\Delta\eta}{2}\right). \qquad (2)$$

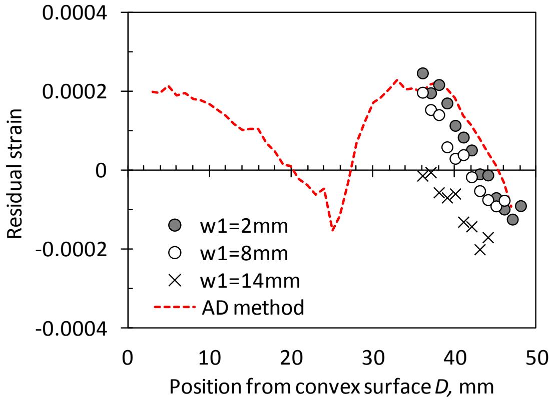

Fig. 1 Normal strain distributions of the plastically bent steel plate.

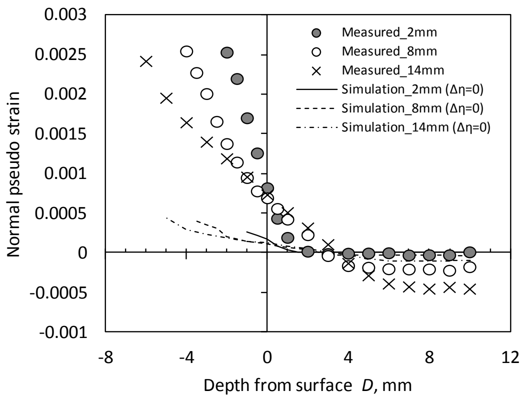

Fig. 2 Normal strain distributions in the annealed steel plate and their simulations without consideration of beam divergence.

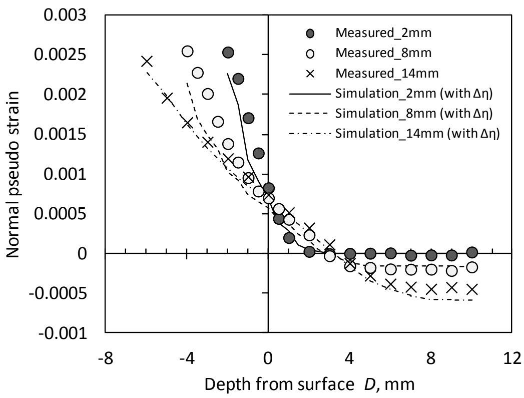

Fig. 3 Normal strain distributions in the annealed steel plate and their simulations in consideration of beam divergence.

As shown in Fig. 3, the simulations derived from Eq. (2) considered with $\Delta\eta$ exhibited good agreement with measured strain distributions.

[1] S.R. Creek et al., Modeling pseudo-strain effects induced in strain measurement using time-of-flight neutron diffraction,http://www.isis.stfc.ac.uk/instruments/engin-x/publications/modelling-pseudo-strain-effects-induced-in-strain-measurement6516.pdf