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# Development of 1-D Position Sensitive Neutron Detectors for Residual Stress Measurements

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Because of the small gauge volume in residual stress measurement, it requires a detector with a wide detection window to get faster measurement. One dimensional position-sensitive neutron detector (PSND) has been developed at HANARO, KAERI. The PSDs are $^3He$ and $CF_4$ filled multi-wire proportional counter with delay line readout, which have easy expandability of window size and simpler construction of data acquisition electronics. The detectors have active windows of 200 mm×100 mm, 120 mm×80 mm and spatial resolutions of 2.5 mm and 1.5 mm, respectively. Because the height of the detection window is increased by to 100 mm and detector performance is better, the overall measuring efficiency is 3.6 times higher than our old detector.

KEYWORDS: position sensitive detector, gas detector, neutron diffraction, residual stress

## §1. Introduction

It is well known that the components in the heavy industrial structures have residual stress resulting in failure in operation. The residual stress may affect the service life of the components, causing cracks and fractures. Great efforts have been made for many years to measure nondestructively the amount of residual stress in those structural components.[1–4] An optional diffractometer specialized for the residual stress analysis has been developed at HANARO center.[5,6]
X-ray and neutron diffraction are known to be powerful in measuring the stress distribution nondestructively. The advantage of neutron over the conventional X-ray is in principle the capability of the neutron beam to penetrate the material. This enables the measurement of stress with neutron to extend to the depth of a few centimeters ($\sim$ 2.5 cm in steel), while the stress fields measured by X-ray are limited only to the depth of $\sim$100 $\mu$m. The volume resolution of the material measured by neutron is normally $\sim$10 mm$^3$, which is much greater than the fraction of 1 mm$^3$ used in X-ray measurement. The intensity of scattered neutron is however low even for such a measurement volume and the position sensitive detector is usually required to speed up the data collection.
The object of this development is to improve the detector system for residual stress measurement. Two sets of one-dimensional position-sensitive neutron detectors were developed for this experiment. The detectors have a higher detection window than the conventional co-axial type detectors to get faster measurement. The characteristics of the detectors are described and compared with our old detection system, a single wire type position sensitive neutron detector of 25 mm active window height.

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## §2. Description of the Detectors

The dimension of the active area of the position sensitive neutron detector is defined by its application. Two gaseous chambers with delay line readout were built. The first prototype chamber (PSND200) was designed and fabricated to study the construction and performance of such detector system with detection area of 200 mm×100 mm.[7] The second chamber (PSND120) with a better position resolution has a sensitive area of 120 mm×80 mm. The major design parameters of the detectors are summarized in Table I. Figure 1 shows the picture of the fabricated two detectors.

Table I. Design parameters of the two detectors.

| Parameters | PSND200 | PSND120 |
|---|---|---|
| Sensitive area($mm^2$) | 200x100 | 120x80 |
| Detection thickness(mm) | 22 | 15 |
| Detection gases(atm) | $^3He(3.1)+CF_4(2)$ | $^3He(4)+CF_4(2)$ |
| Anode wire diameter($\mu$m) | 10 | 15 |
| No. of cathode strips(EA) | 100 | 60 |
| Total delay time(ns) | 180 | 180 |

To characterize the performance of the PSDs we carried out specific measurements of position resolution, linearity and homogeneity, etc. The position resolution functions of the PSND200 and PSND120, measured using a 1 mm slit width, are shown in Fig. 2. The full width at the half maximum(FWHM) of the position resolution function of PSND200 is much wider than that of PSND120. Subtracting the effect of 1 mm slit width the position resolution of the detectors, of FWHM, are 2.8 mm and 1.8 mm, respectively. In the case of delay line detectors, the linearity measurements mainly evaluate the quality

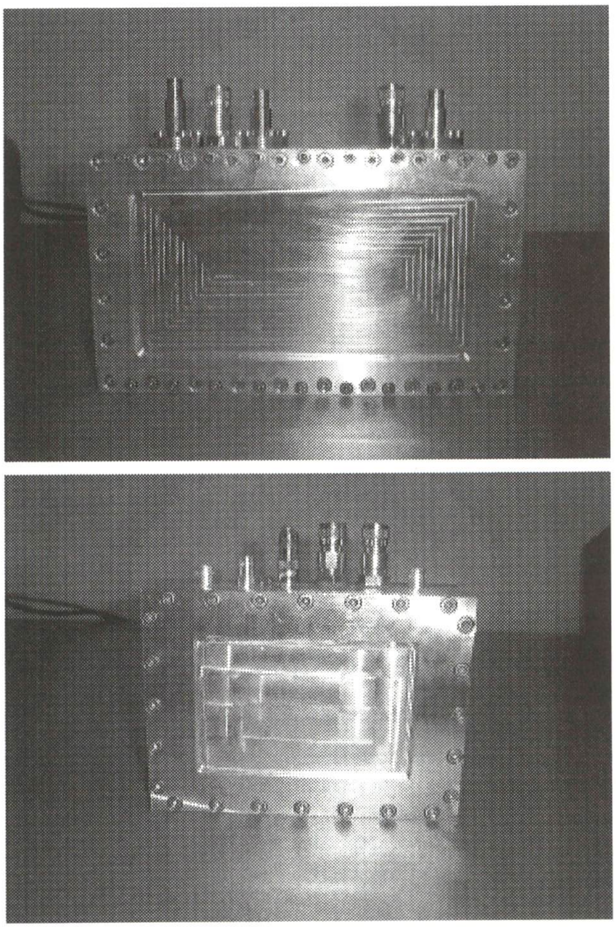

Fig. 1. The fabricated PSND200(up) and PSND120(down)

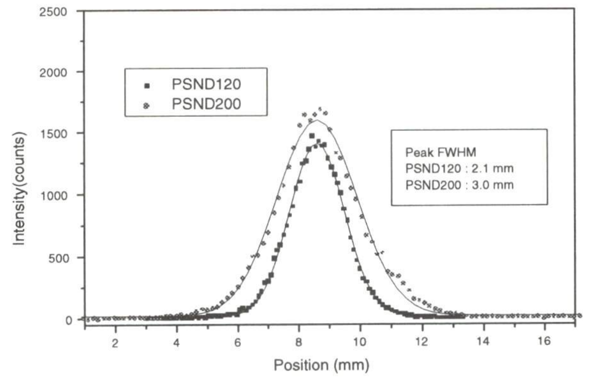


Fig. 2. Position resolution function of PSND200 and PSND120. Slit width is 1.0 mm. The FWHM of PSND200 is 3.0 mm and that of PSND120 is 2.1 mm. By subtracting the effect of slit width the position resolution of the detector is 2.8 mm and 1.8 mm, respectively.

of the delay line. Irregularities in the delay line construction may introduce linearity losses. All of the delay line components, inductors and capacitors, were selected within 5 % deviation around its nominal values. The linearity of the detectors was tested by highly collimated beam by step scan measurement. The deviation of the measured position of the detectors, so called the integral non-linearity, was below 0.1 % of the active length of the detectors. The homogeneity, i.e. the differential non-linearity, of the detectors was tested by diffraction of a plexiglass sample and resulted in about 3 %.

Comparison of the neutron detection characteristics of PSND200 and PSND120 was made by measuring reflections (110), (002) and (112) of Fe in a steel rod of 2 mm diameter and 20 mm height. The first collimator was soller type of 20' divergence and the second collimator was single-slit type with cross-section 6 mm×60 mm. The steel rod was installed on the sample position vertically. The shielding for the detectors was made of the combination of high density polyethylene, boronated polyethylene, cadmium sheets and boronated rubbers. Figure 3 shows the assembled shielding containing one of the detectors. The measurements showed that integral intensity of diffraction peaks for PSND200 is about 1.9 times higher than those for PSND120, while width of the peaks are practically the same. The results were shown in Fig. 4. Integrated intensity of the PSND200 is higher than that of PSND120 due to the such factors as detection window height (1.25 times), detection efficiency (1.1 times) and other operating conditions.

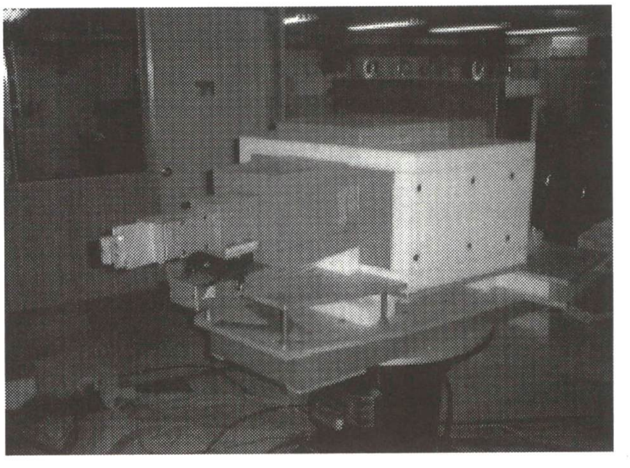

Fig. 3. The shielding for the detectors

In order to compare PSND200 with our old detector, which was used during the early development of residual stress measurement at HANARO, the aluminum VAMAS (Versailles Project on Advanced Material and Standards) TWA-20 round robin sample was measured. The VAMAS TWA-20 was organized to stanardize residual stress measurement methods by neutron diffraction. It was made from aluminum alloy 7075 and was consisted of a ring and a plug which had been joined in a way that mutual constraint occurred. The outer sample diameter was 50 mm, the inner ring diameter(=outer plug diameter) was 25 mm, and the height of the sample was 50 mm. Experimental conditions were the same as that measured by the old detector in 1999.[5] Radial component of strain was measured at the distance from the sample center : R=0(center) and R=20 mm using reflection (113) of aluminum ($2\theta$ = 97.34°)(Fig. 5 and Fig. 6).

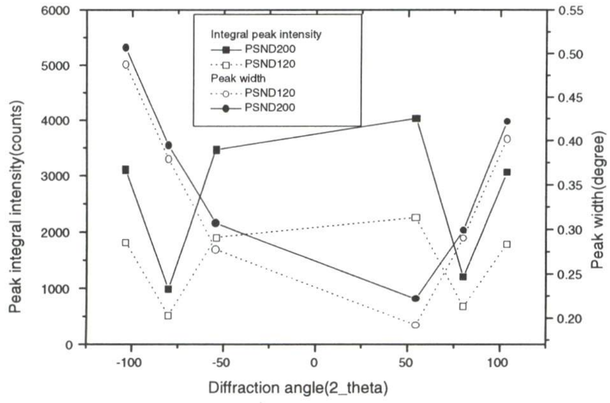


Fig. 4. The integral intensity and width of diffraction peaks measured by PSND200 and PSND120 in parallel($+2\theta$) and anti-parallel($-2\theta$) position of steel rod $\phi 2$ mm, 4 mm height. The reflections of steel rod are (110) ($2\theta = 53.90°$), (002)($2\theta = 79.88°$), and (112) ($2\theta = 103.50°$), respectively.

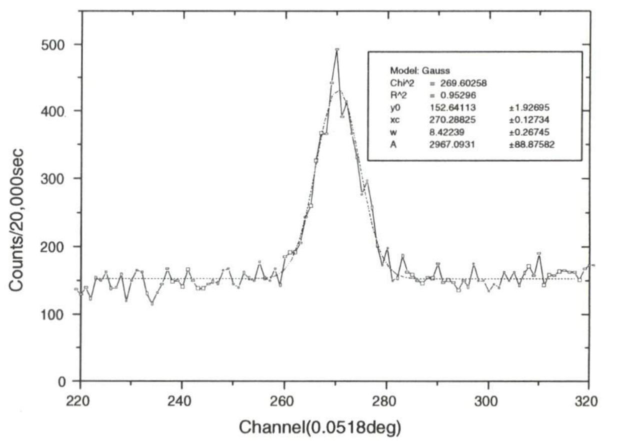


Fig. 6. The reflection (113) measured by old detector in aluminum VAMAS round robin sample in radial direction at point R=0 mm.

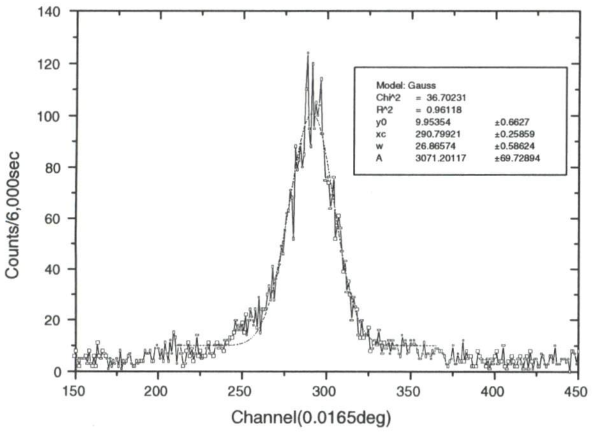


Fig. 5. The reflection (113) measured by PSND200 in aluminum VAMAS round robin sample at radial direction in point R=0 mm.

The measurements showed that the width of diffraction peak was about 31' for both detectors. Integrated intensity of the peak for PSND200 was about 3.6 times higher than that for the old detector. Another advantage of PSND200 over the old detector was the fact that the peak background ratio for PSND200 was much higher than that for old detector. And the positional error in peak center position, which is the main criteria for residual stress measurements, was lower for PSND200 too.

## §3. Conclusion

Two 1-dimensional position sensitive neutron detector of different design parameters, e.g. window height were designed, fabricated and tested for residual stress measurements. Intensity of diffraction peak was 3.6 times higher than that of our old detector. The experiments showed that a decrease of position resolution from 1.8 mm to 2.8 mm was not due to a noticeable decrease of peak resolution. The neutron detection efficiency is more important than positional resolution for residual stress measurements under the required limitation of strain precision.

## Acknowledgements

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