§13. Change in Interlaminar Shear Strength and Fracture Mode of Glass Fiber Reinforced Plastics by Gamma Ray Irradiation

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To realize a fusion reactor, a large-scale superconducting magnet system is desirable and must be equipped in a new energy system. The fusion reactor will require high magnetic field of over 15 T and it means a new large-scale superconductor carries a large travel current must be developed in near future. At the same time, special consideration for neutron irradiation must be performed when the development would be carried out, since the generated neutron by D-D or D-T reaction in the fusion reactor would be streaming out of plasma vacuum vessel and/or penetrate a shielding blanket, and finally the neutron reach the superconducting magnet. The nuclear heating by the reached neutron would increase the heat load enormously to the cryogenic system for the magnets. Also, the superconducting properties of the superconducting materials would be changed by the irradiation, in other words, by knock-on effect, and the materials would be activated by generating the isotopes.

The electric insulation material is also irradiated and would be degraded by the neutron and gamma ray. It is vary important to clear the effect and mechanism of the degradation from the view points of materials strength engineering and magnet design technology. To simulate the neutron radiation environments, the irradiation tests are used to be carried out in a fission reactor. However, the specimen size is usually very small because of the limitation of space in the reactor. Therefore, the miniature specimen technology, how to evaluate the materials properties precisely with small specimens, is very essential.

Up to now, a so-called short beam method (three-point-bending) has been proposed as a evaluation process of interlaminar shear strength (ILSS) of glass fiber reinforced plastics (GFRP), and it is known that it gives a good result with relatively smaller specimens. The basic researches have been undertaken in these years using commercial GFRP, G-10CR, and the effect of the gamma ray irradiation on ILSS was investigated empirically based on the precedent studies.

The specimen configuration was 2.5 mm thick, 10 mm wide and 15 mm long, and the span for the three-point-bending was 12.5 mm. The radius of the loading and supporting jigs was 6 mm. Stroke rate of 0.75 mm/min was adopted and the tests were carried out in liquid nitrogen (77 K). The ILSS was obtained by the following equation:

$$\sigma_{ILSS} = (3 \times P_B) / (4 \times b \times h),$$

where P_B is the maximum bending load, b is the specimen width (10 mm) and h is the specimen thickness (2.5 mm).

To investigate the effect of glass cloth structure on the ILSS, two types of specimen were prepared. The first one was the original plate thickness specimen as shown in Fig. 1. The other was machined out of the 13 mm thick plate as shown in Fig. 2. Each specimen was designated as 'non-sliced' and 'sliced' specimen respectively.

The gamma ray irradiation was performed using Co60 at Osaka University.

The results are shown in Fig. 3. As an increment of the gamma ray dose, the ILSS decreases and becomes almost zero at 10 MGy. The clear degradation started at around 0.5 MGy. In the case of non-sliced specimen, the fracture mode changed from Interlaminar to bending fracture at the bottom of loading point or shear fracture on the plane connecting loading and supporting points. The sliced specimen did not show the Interlaminar fracture even on the non irradiated condition. The cloth structure at the midsection of the thicker GFRP plate would not be so strong that the cloth layer would be destroyed by bending-tension or the shear mode crossing the cloth layer structure.

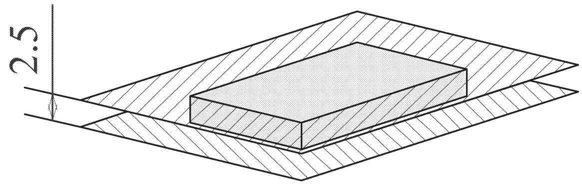

Fig.1 Location of "non-sliced" specimen in the plate.

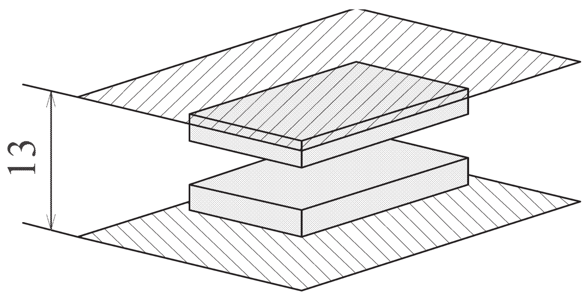

Fig. 2 Location of "sliced" specimens in the plate.

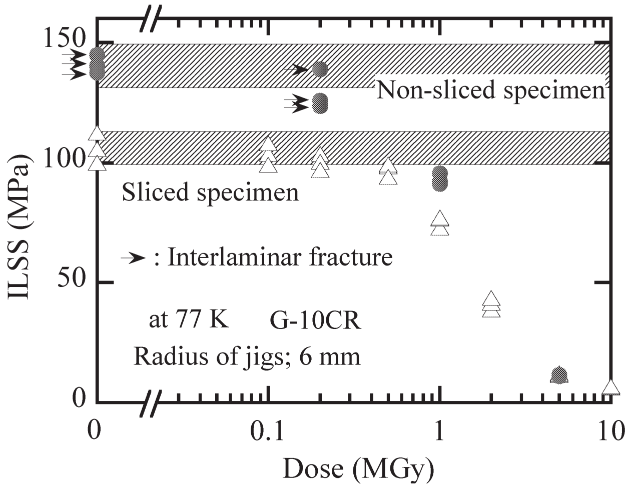

Fig.3 Summary of ILSS test results at 77 K.