§13. Study on the Irradiation Effect of Organic Insulation Materials for the Superconducting Magnet

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1. Introduction

The organic composite material to be used for the insulation system in the fusion magnet is needed to withstand high dose irradiation, cryogenic temperature and high complex combined stresses. This study focused on the effect of combined stress on the Glass Fiber Reinforced Plastic (GFRP). GFRP used for the insulator in the fusion superconducting magnets has been operated under compressive/shear load caused by electromagnetic force. The radiation induced by the nuclear reaction degrades the insulating properties, which results in the degradation of the magnet performance. Thus, it is necessary to develop the insulator with high radiation resistance under mechanical loads. In previous study the mechanical strength has been evaluated in terms of the uniaxial shear strength[1]. The shear strength under the compressive stress should also be investigated considering the actual conditions. In this study, the interlaminar shear strength (ILSS) tests under compressive loads were conducted in the irradiated insulator, and the irradiation effect on the mechanical strength was evaluated.

2. Experimental

In this study, two types of insulators were fabricated. 29 glass cloths and 28 polyimide films were laminated alternately and impregnated with resin under vacuum. We used two types of resins; one is the epoxy resin with amine series hardener (EP), the other is the mixed resin of cyanate ester and epoxy resin with weight ratio of 4:6 (CE). The specimens were cut out from insulators as shown in Fig.1 and were irradiated with gamma ray by ^{60}Co up to 10 MGy. Then the ILSS tests under compressive loads were conducted at liquid nitrogen temperature using the tilted test jig (Fig.2). When the load W is applied to the tilted jig with angle θ, the load W is divided into compressive $W\sin\theta$ and shear load $W\cos\theta$, and the mechanical strength is calculated from the fracture load. The test was performed in different stress ratios by changing the angle of jig.

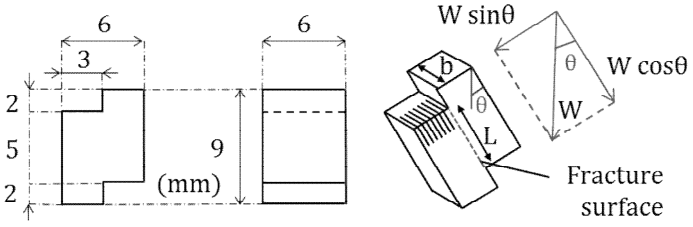

Fig. 1. Geometry of specimen and load direction.

2. Results and discussions

Fig.3 shows the test results. The ILSS was increased with compressive stress. Though the mechanical strength of EP-insulator was decreased by irradiation of 10 MGy, that of CE-insulator was not decreased, and hence the failure envelope of irradiated CE-insulator was similar to that of unirradiated one. It can be concluded that CE-insulator shows high radiation resistance.

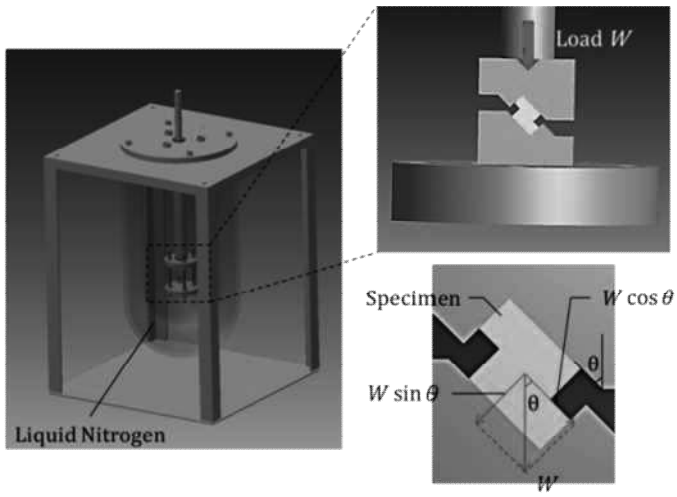

Fig. 2. Schematic designs of the test apparatus.

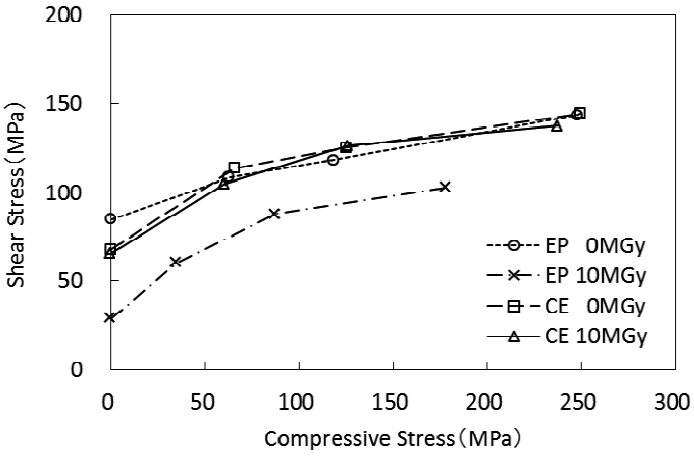

Fig.3 Fracture stress of the insulators before and after irradiation.

3. Conclusion

It is necessary to examine the shear strength under the compressive stress considering the actual conditions. The combined compressive/shear stress was applied to the irradiated insulator, and its irradiation effect on the mechanical strength was evaluated. As a result, it was found that CE-insulator has high radiation resistance and is suitable for fusion magnets.

1)T. Takahashi, F. Mishima, Y. Akiyama, S. Nishijima: CSSJ Conference 90 (2014) 206.