§4. Small Specimen Test Techniques for IFMIF

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International Fusion Materials Irradiation Facility (IFMIF) is essential to evaluate the material performance under fusion relevant environment.

The required irradiation volume for fracture toughness measurement is estimated to be 560cc that exceeds the irradiation volume of the speck of IFMIF where the available displacement damage is 20dpa/year. In order to effectively produce IFMIF irradiation database, reduction of the specimen volume is strongly demanded without loosing data reliability by the specimen miniaturization.

Material used in this study was the JLF-1LN steel (JLF-1 JOYO-heats). The steel plate of 30 mm thickness was heat-treated at 1323K for 1h and air-cooled (normalizing), and then tempered at 1053K for 1h, followed by air-cooling (tempering). Four different sizes of compact tension (CT) specimens were fabricated. Prior to the fracture toughness test, a fatigue pre-crack with a ratio of the crack length to specimen width (a /W) of 0.5, was introduced to the specimen until the final K value to be 21.7, 21.4 and 20.1 MPa√m for 1CT, 1/2CT and 1/4CT specimen, respectively. And then the specimens were side-grooved by 25% (25% SG) of their thickness with the root radius of 0.1 mm. The fracture toughness tests were carried out at room temperature referring to the ASTM E1820-99a by means of the unloading compliance method.

The J_Q values obtained for the 1t-1CT and 1/2t-1CT specimens were 425 and 560 kJ/m^2, respectively. The fracture toughness increased as decreasing in the specimen thickness. On the other hand, the fracture toughness decreased when the specimens were miniaturized while keeping the similar figure, resulting that the J_Q values for the 1/2CT and 1/4CT specimens were 382 and 300 kJ/m^2, respectively.

The weibull distribution analysis (Fig.1) of the measured fracture toughness is necessary for dealing with a variability in the obtained data such as J_Q. The parameter *m* (shape parameter) is determined from the slope of the line. For each line, the values were ranging from 10 to 14, suggesting that fracture toughness data with high reliability is obtained even for the miniaturized 1/4CT specimens.

The fracture toughness increased as decreasing in the specimen thickness. Two of the possible explanations of the above results are as follows.

1) It is considered that the plane stress state becomes predominant as specimen thickness decreases, and the plastic zone size at the crack tip increases near specimen side surfaces. Since the energy spent on the plastic diformation increases, the fracture toughness increased.

2) The crack growth occurs at the weakness part of crack front (weakest-link theory), it is considerd that the fracture probability increases as the specimen thickness increses, and the 1t-1CT specimen presented a low fracture toughness. However, since the weibull distribution form of the 1t-1CT were similar to 1/2t-1CT, it is considered that the first factor is more predominant in the specimen thickness effect on the fracture toughness obtained for the above two type of specimens.

Among the obtained J_Q values for the different size of specimens, only the value of 1CT specimen was valid and those of other size of specimens were invalid, according to the valid criteria of equation. However, the reduction of fracture toughness coupled with hardening, which will be induced by high dose of neutron irradiation, may decrease the specimen thickness that satisfies the criteria equation. An assumption that the irradiation-induced reduction of fracture toughness and irradiation hardening is 40% and 300MPa, respectively, the minimum thickness required to keep a valid value was estimated to be 9 mm, indicating that even after neutron irradiation, the fracture toughness obtained with using 1/4CT specimen will still be in valid.

Since the first wall thickness is estimated to be less than 5 mm for ferritic steel-water blanket system, the obtained fracture toughness values of the first wall were always invalid before and probably even after irradiation. It is demanded that new valid/invalid criterion can be established for thin specimens to provide a valid database, if necessary, of fracture toughness of fusion blanket structural materials.

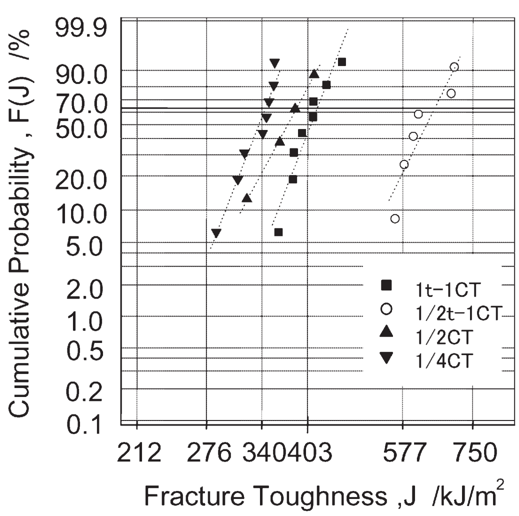

Fig. 1 Weibull plots of fracture toughness JQ obtained from the CT specimens of JLF-1 at various specimen sizes.