§14. Evaluation of Validity of Master Curve Method to Measure the DBTT Shift of Ferritic Steels for Blanket Structural Components

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The shift of the ductile-brittle transition temperature (DBTT) has been considered to be critical for blanket structure components which were made of reduced activation ferritic steels. The evaluation of the DBTT shift under the synergistic effects of high dose of neutron irradiation and transmutation helium generation is one of the most important missions of high energy neutron sources for fusion materials development.

In this research, the feasibility of Master Curve Method (MCM) to evaluate DBTT shift of ferritic steels was investigated with use of miniaturized compact tension (CT) specimens.

The material used was a reduced activation ferritic steel, JLF-1LN, whose nitrogen concentration was reduced to 150wt.ppm. The CT specimens with different geometries with keeping similarity were produced, as shown in Fig. 1 that describes the 1/4, 1/2 and standard size specimens. Fracture toughness was measured by following the ASTM standard E813 (E1820-99a). The master curve was expressed by the following equation:

$$K_{Jc(med)} = 31 + 77\exp\left[0.019\left(T - T_0\right)\right] \qquad (1)$$

where T_0 is the reference temperature. As for the normalization of the fracture toughness obtained by miniaturized specimens to that of standard specimens, the equation (2) was adopted with an assumption that the fracture was governed by the weakest link model.

$$K_{Jc(1T)} = K_{\min} + \left[K_{Jc(xT)} - K_{\min}\right]\left(B_{xT}/B_{1T}\right)^{1/4} \qquad (2)$$

where B_{xT} and B_{1T} is the specimen thickness of the miniaturized specimen and the standard specimen, respectively. In order to simulate irradiation hardening, a part of the steels was heat-treated at a different condition to increase the hardness of the steel. The difference in the DBTT between the steels measured by impact test was 84K.

The master curves of the steels with different hardness are shown in Fig. 2(a) and (b). The fracture toughness was measured with 1/2 size specimen for the normalized and tempered steel, and the standard specimens for normalized specimens. Well-defined master curves were obtained for both the standard and 1/2 size specimens, and the DBTT shift was estimated to be 78K that is rather close to the value obtained by impact test.

As for the 1/4 specimens, however, it was very difficult to get the fracture toughness values around 100 MPa•m$^{1/2}$. Finally, no master curve was obtained for both the steels with use of 1/4 size specimens. This is considered to be due to an abrupt transition behavior from brittle to ductile fracture in the miniaturized specimens, especially for 1/4 size CT specimens.

The DBTT shift of a ferritic steel was successfully measured by MCM with use of 1/2 size and standard size CT specimens. Further efforts are necessary to develop small specimen test technology utilizing smaller CT specimens, such as 1/4 size specimens.

Fig. 1. The CT specimens used to evaluate the validity of the Master Curve Method to evaluate the DBTT shift of ferritic steels.

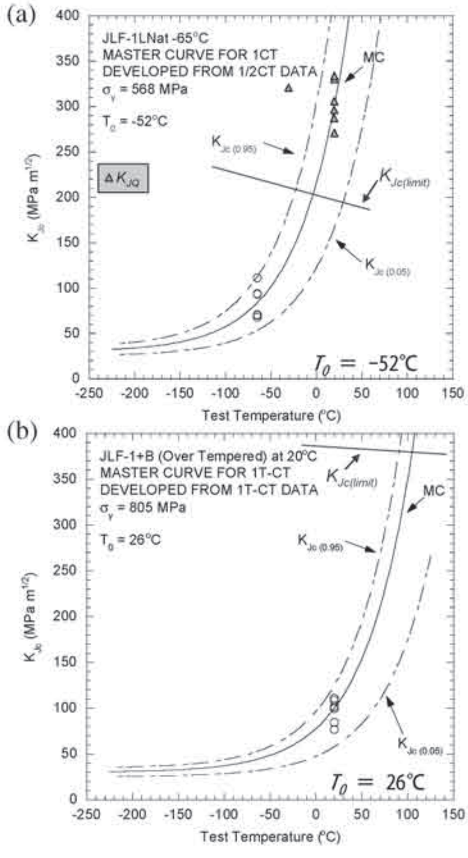

Fig. 2. The master curve of: a) normalized and tempered ferritic steel with use of 1/2 size specimens, and b) normalized steel with use of standard specimens.

Reference

1) Ono, H., Kasada, R., Kimura, A., J. Nucl. Mater., 329-333 (2004) 1117-1121.