Improvement of irradiation response of toughness and ductility in F82H

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The reduced activation ferritic/martensitic (RAF/M) steel F82H is recognized to be a leading candidate material for in-vessel components in a future fusion DEMO reactor, as well as that for ITER test blanket modules (TBM) [1]. Examination of the neutron irradiation response of RAF/M steels has been carried out mainly in JA-US collaborative experiments using the High Flux Isotope Reactor at Oak Ridge National Laboratory. The results of recently completed post-irradiation examination demonstrated a remarkable improvement in the irradiation-induced degradation of fracture toughness after optimizing and tightening the heat treatment condition, as well as by addition of minor alloying element of tantalum to 0.1%. The degradation of fracture toughness was evaluated by the shift of ductile to brittle transition temperature (DBTT-shift). DBTT-shift and reduction of ductility by irradiation have been recognized to be critical issues for RAF/M steels; therefore, the beneficial effect of the optimization of tempering condition may be to extend the service conditions of RAF/M steels. In this paper, the improvement of the irradiation response of DBTT is mainly reported. The specimens were tempered between 700 and 800°C for 0.5 to 10 hrs before irradiation. Results showed that longer tempering times are beneficial for reducing the post-irradiation hardness. Miniaturized bend bar specimens (half size of 1/3-CVN specimen) with fatigue pre-crack were tempered at higher temperature and/or for longer time. The specimens were irradiated to 20 dpa and tested at several temperatures. Figure 1 shows the results. Data points for IEA-F82H show the result at a reference tempering condition of 750 °C for 1h. Data for a longer tempering time (700°C for 10 hrs), noted as a "Mod1 Series" clearly exhibit lower DBTT after irradiation. The DBTTs are about 0 and 50°C for Mod1 and IEA, respectively. The DBTT reduced by about 50°C. Although the 20 dpa damage level is much less than the target of 100 dpa for DEMO, the tendency for the DBTT-shift to saturate with increasing damage level suggests that the large improvement of irradiation performance of DBTT would be maintained at higher damage levels [2].

Improvements of post-irradiation toughness and ductility by optimization and tightening of tempering condition are quite beneficial to expand the service condition of RAF/M and seem to deliver more flexibility for DEMO design. The methodology of improving post-irradiation toughness and ductility is also expected to be applicable for other RAF/M steels.

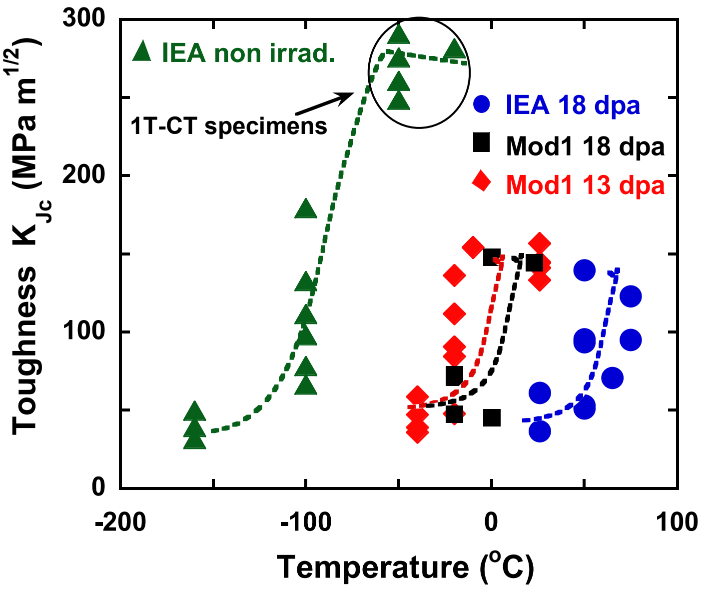

Fig. 1. Temperature dependence of fracture toughness in F82H Results indicate remarkable reduction of radiation effect on fracture toughness due to optimization/tightening of tempering condition. Miniaturized bend bar specimens were used. Data shown in circle were measured from large size (1T-CT) specimens.

Reference

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[2] S. Jitsukawa, K. Suzuki, N. Okubo, et al., Nuclear Fusion 49(2009)115006