§71. Irradiation Effects on Joining/Coating of Low Activation Structural Materials

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In order to employ oxide dispersion strengthened steel (ODSS) in fusion blanket systems having large and complex structures, reliable bonding and welding techniques are required. The application of conventional melting-solidification welding techniques such as tungsten–inert gas welding for ODSS joining may result in the disruption of fine-scaled microstructures, especially nano-oxide particles, and consequently the loss of high-temperature strength because of the agglomeration or growth of featured microstructures.

Solid-state diffusion bonding (SSDB) does not create a molten zone at the bonding interface, which prevents or minimizes the degradation of featured microstructures. Therefore, SSDB can be potentially adopted to bond large areas as well as pre-machined components, complex shapes and interfaces. Because no bulk plastic deformation occurs, SSDB can be used to fabricate blanket structures of fusion reactors.

The objective of this research is to investigate the effects of neutron irradiation on the performance of ODSS SSDB joints.

The ODSS used as the base material in this study is Fe(bal.)–15Cr–2W–0.2Ti–0.35Y_2O_3. The ODSS was fabricated via mechanical alloying and hot extrusion. After mechanical alloying, the powders were sieved and charged in mild steel capsules. The capsules were degassed to 10^{-3} Torr at 400 °C for 3 h. Hot extrusion was carried out at 1150 °C for rod-shaped samples. Hot rolling and heat treatment were carried out at 1150 °C for plate-shaped samples. Finally, the samples were cooled in air.

The samples were cut into 20 × 12 × 12 mm^3 test pieces for bonding, and the surfaces to be bonded were wet-ground with SiC emery papers; finally, they were buff-polished such that they had an average roughness of 0.25 lm. After surface polishing, the samples were stored in acetone for cleaning and to prevent surface contamination.

A hydrostatic vacuum hot press furnace was used for diffusion bonding in this study. Two ODSS blocks were placed vertically between the pressing punches and were linearly heated up to the bonding temperature at a rate of 10 °C min^{-1}. The bonding temperature was maintained for various durations in a high-vacuum atmosphere (5 × 10^{-4} Pa), under a hydrostatic pressure of 25 MPa in a uniaxial compressive loading mode. After the bonding process, the hydrostatic pressure was reduced and the samples were cooled in the furnace.

Microstructure observation revealed that the SSDB joint had a good bonding interface without voids and inclusions. To compare its bonding strength with that of the base material, tensile tests were carried out at room temperature on the base material and SSDB joint for each bonding orientation relationship. The stress–strain curves obtained for the base material and SSDB joint are shown in Fig. 1. The base material exhibits typical anisotropic behavior, i.e. it can be strained to a greater degree with L–R orientation than with other orientations; this is a typical characteristic of hot-extruded ODSS, which have elongated grains parallel to the loading direction. Significantly, nearly the same anisotropic tensile behavior was observed in the case of the SSDB joints. All the SSDB joint specimens tested at room temperature were fractured in a ductile mode, showing a necking at several micrometers from the joint interface. After the tensile test, anisotropic fracture behavior could also be observed in the base material.

In the first year of this project, ODSS joints were successfully fabricated for JMTR irradiation as well as HFIR irradiation in ORNL, US. The post-irradiation experiments will be started from August in 2011.

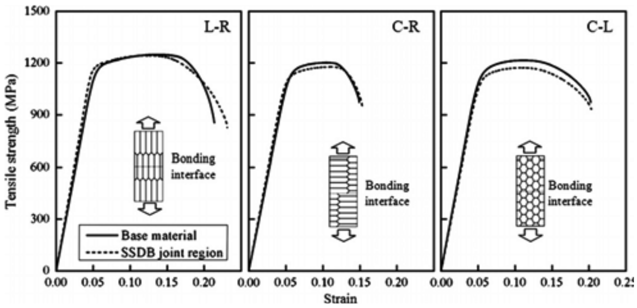

Fig. 1: The hardness distribution across the joint boundary of SSDB (upper) and brazing (bottom).