§31. R&D of W-coat Processing on Low Activation Structural Materials

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Tungsten (W) coating R&D on low activation materials is essential for the fabrication of blanket first wall and diverter components of fusion DEMO reactors. The vacuum plasma spray (VPS) process is practical for coating a large area because of its relatively high coating rate. Solid state diffusion bonding (SSDB) technique is desired for the oxide dispersion strengthened steels (ODSS) of which the high performance depends on the dispersion morphology of the oxide particles. In the present study, W coatings were fabricated on various low activation materials by the VPS process and the W-ODSS joining were conducted for bulk-W and an ODSS. The objective of this research is to characterize the coated materials and joints from the view of the microstructure and mechanical properties. In this short paper, a part of the research on W-ODSS joints is reported.

The material used were high-Cr ODS ferritic steel K1 ((Fe-19Cr-0.3Ti-0.3Y2O3) and pure W. The fabrication of ODS ferritic steel is described in the literature [1]. Insert material for brazing was a Fe-based amorphous alloy with a thickness of 25μm, called ALLOY 2605S-2 (Fe-3B-5Si), which contains 3wt. % B and 5wt. % silicon as a melting point depressant of Fe. The melting point of the insert materials was measured to be 1423K by means of differential calorimetric analysis. Brazing was performed in a vacuum less than 10^{-3} Pa, for 30min, 1h or 4h. SSDB was also performed to compare the joint performance with brazing. The temperature of both the brazing and SSDB was 1453 or 1473K, which are slightly higher than the melting point of insert material.

Small punch (SP) tests were carried out to evaluate the strengths of joining. The geometries of specimens for SP test are shown in Fig. 1. In order to load a large tensile stress on the joint; the SP joint specimens were punched out so as to come the joined line 0.5mm away from the center of the specimens.

The brazed joint is divided into 5 layers: W matrix (W), inter-diffusion layer in insert material (layer 1), insert material (layer 2), and diffusion effected zone of ODS steel (layer 3) and ODS steel matrix (ODS steel). The layer 1 appears to consist of two sub-layers: sub-layer 1 showing mesh-like alternate distribution of Fe and B, and sub-layer

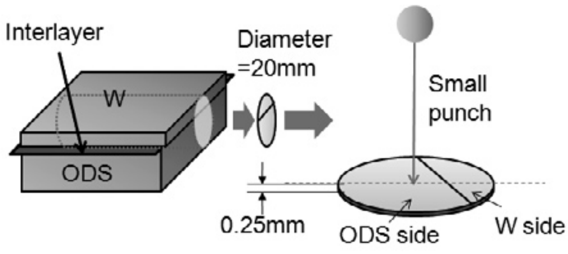

Fig. 1: Sampling SP specimen of the ODS steel-W joint. The thickness of W matrix was about 0.8mm.

2 in which B was homogeneously concentrated. As for Si, the distribution profile is same as Fe. It is noted that Si distributed in both ODS steel and W. All over the layer 1, there are Cr and W. In the layer 2 and layer 3 of the brazed joints at 1473K for 1 h and 4 h, W was distributed in grain boundaries of Fe-3B-5Si insert and also of ODS steel. W diffuses at longer distance with increasing the brazing time. In the layer 3, there were large precipitates in which Cr and C were concentrated.

Fig. 2 shows the SP load-deflection curves of brazed and SSDB joints measured at room temperature. For the brazed joint at 1473K for 4h, abrupt load drop was observed twice in the curve; the first drop (pointed by red filled arrow) represented the maximum fracture load of joint interface and the second drop (pointed by open red arrow) represented the maximum load of ODS steel matrix. The first drop was identified as the maximum load of the brazed joint at 1473K for 4 h. Both the maximum load and deflection of SSDB joint were higher than those of brazed joints. For brazed joints, the maximum load decreased with increasing brazing time.

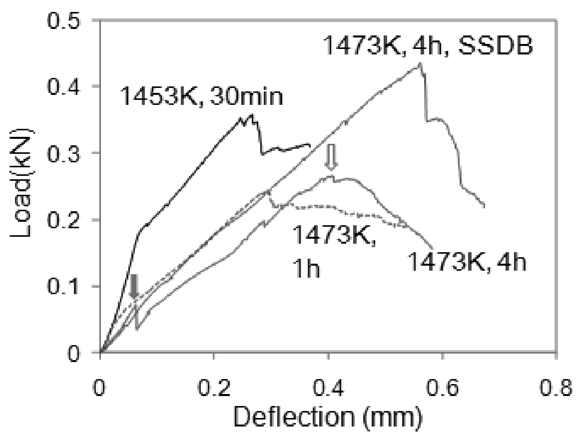

Fig. 2 Load-deflection curves of brazed and SSDB ODS steel-W joints measured at room temperature.

It can be concluded that the strength of SSDB joint was higher than those of the brazed joints. The weakness of the brazed joints than the SSDB joint is due to the thick brittle W-boride in the inter-diffusion layer. Heat-loading test is necessary to confirm the acceptability of the SSDB joints. As for brazing, elimination of reaction phases is considered to be essential.

1) N. Okuda, R. Kasada, A. Kimura, J. Nucl. Mater. 386-388 (2009) 974.