§20. Diffusion Bonding for 9Cr-ODS and JLF-1 Reduced Activation Ferritic/Martensitic Steels

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Reduced-activation ferritic/martensitic (RAFM) steels, such as JLF-1, have been developed as the structural materials for fusion blanket. Recently, oxide-dispersion-strengthened (ODS) steels with reduced-activation composition has been also developed as armor for the high temperature part of the blankets to enhance the operation temperature due to high creep strength. Therefore, bonding technique for the ODS steels to JLF-1 steel is essential for its application to the blanket system. The present study fabricated diffusion bonding joints of the candidate 9Cr-ODS steel and JLF-1 steel by hot isostatic pressing (HIP) process. Characterizations of the bonding by mechanical property tests and microstructural analysis are undergoing.

Table 1 lists the composition of 9Cr-ODS steel and JLF-1 steel. The identification was JOYO heat for JLF-1 steel. The final heat treatment for 9Cr-ODS was a normalizing at 1323 K for 1 hr followed by tempering at 1073 K for 1 hr. The final heat treatment for JLF-1 was a normalizing at 1323 K for 1 hr followed by tempering at 1053 K for 1 hr. The specimen size of 9Cr-ODS for bonding was 5 mm in thickness and 24 mm in diameter, while JLF-1 was 20 mm in thickness and 24 mm in diameter. The contacting surface of the specimens for the bonding were mechanically ground and electro-polished. As shown in Fig. 1 (a), the ODS disk was sandwiched with the two JLF-1 blocks and canned into a SS300 soft steel capsule by electron beam welding. The capsule was HIPed at 1273 for 3 hr under 191 MPa. After the HIPing, miniature Charpy V-notch impact specimens, TEM specimens, tensile specimens and coupon specimens for hardness tests were machined with an electro-discharge machining.

Figure 1 (b) shows the cross section of the bonding specimen after the HIPing. No defect was found in the optical microscope analysis. In a microstructural analysis with scanning electron microscope after a chemical etching, a small gap was observed at the boundary between 9Cr-ODS and JLF-1. Hardness tests indicated both softer and harder area at the boundary between 9Cr-ODS and JLF-1. These data suggest an reaction layer at the boundary. Further analysis on the boundary by transmission electron microscope is necessary to identify the reaction layer.

Hardness of 9Cr-ODS and JLF-1 steels were 406 and 213 VHN at as-NT condition (before HIPing), respectively. They were 342 and 398 VHN after the HIPing. 9Cr-ODS was softened, while JLF-1 was hardened during the HIPing. HIP process consists of heating and cooling. Hardness of the RAFMs including 9Cr-ODS steel depends on especially the cooling condition. Hardness is increased with increasing cooling rate due to martensite transformation. The cooling rate in the HIP process could be smaller than that for the final heat treatments before HIPing. The cooling rate in the HIPing might be less than that required for martensite transformation in 9Cr-ODS, therefore it was softened. On the other hand, martensite transformation was considered to occur more effectively in JLF-1 than in 9Cr-ODS, and led to hardening. In order to clarify this mechanism, microstructural observation and recovery tests with isochronal annealing are undergoing. Quenching treatments followed by tempering are planed to moderate the softening of 9Cr-ODS and hardening of JLF-1 during the HIP process. Bonding strength will be evaluated by impact tests, tensile tests and bending tests in the near future.

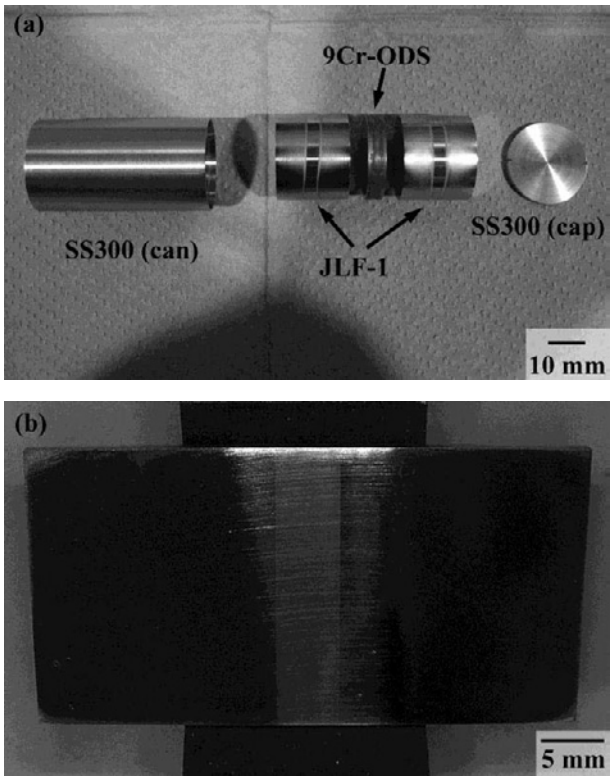

Fig. 1 9Cr-ODS and JLF-1 bonding specimens (a) before EB canning for HIPing and (b) after the HIPing at 1273 K for 3 hr under 191 MPa. Fig. (b) indicates the 9Cr-ODS area in the center of the specimen highlighted by grinding and electro-etching.

Table 1 Chemical composition of 9Cr-ODS and JLF-1 steels (mass %)

Materials	C	Si	Mn	P	S	Cr	W
9Cr-ODS	0.14	0.06	0.09	< 0.005	0.004	9.08	1.97
JLF-1	0.090	0.05	0.49	< 0.003	0.0005	9.00	1.98

Materials	V	Ta	Ti	Y	N	O
9Cr-ODS			0.23	0.29	0.013	0.16
JLF-1	0.20	0.083			0.015	0.002