INTERFACIAL REACTION IN THE TANTALUM-STEEL
EXPLOSION WELD COMPOSITE AT 1 053 K

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Abstract The microstructure of the interface of the explosively welded tantalum-steel composite which had been subjected to heat treatment at 1053 K was investigated by using optical microscopy and electron probe micro-analysis. It was confirmed that a Ta₃C layer grew along the tantalum-steel interface. The carbon diffusion path at 1053 K, going through the γ-Fe, α-Fe, Ta₃C and α-Ta phase regions was identified and interpreted by means of the Fe-Ta-C equilibrium phase diagram assuming that local equilibrium is established at all the phase boundaries.

Key words tantalum-steel bond interface; microstructure; carbon activity; diffusion path

Tantalum and their alloys have high melting points and excellent elevated temperature mechanical properties; they are excellent materials for high temperature corrosion applications such as crucibles, furnace interiors, heat shields and thermocouple heaters in vacuum or inert atmosphere[1]. The long service life and reliability of these materials usually offset their high initial construction and installation costs. Tantalum can be cast effectively for most reaction vessels. It is typically used as thin sheets explosively bonded to a substrate usual steel. The explosively welded tantalum-steel composite combined a corrosion resistant tantalum with an inexpensive high-strength low-carbon steel and thereby lower costs. The specified fabrication size often precludes welding of the clad components at the final gauge. Thus the material may be processed by rolling explosion-welded plates to the desired gauge.

The examination of the carbide layer formed in the tantalum-steel interface is of considerable technical importance. The microstructure of the bond zone usually varies with heating temperature. Heat treatment results in the diffusion of carbon and the formation of carbide layer. The carbide layer will reduce the bonding strength of the composite. The carbon diffusion often goes up-hill. Ågren[2-4] discussed the aspects of carbon up-hill diffusion and the partial equilibrium with respect to carbon between a carbon steel and an alloy tool steel in compound welds. The present authors observed the carbon up-hill diffusion phenomena in the titanium-steel interface, molybdenum-steel interface and the niobium-steel interface[5-6]. In order to evaluate the diffusion path of the tantalum-steel interface, a microstructural study of bond zone was carried out after a long-term annealing at 1 053 K. This paper describes the investigation into the Fe-Ta-C phase diagram which can be of great help in interpreting the formation of the carbide layer in the tantalum-steel bond interface.

1 EXPERIMENTAL PROCEDURE

The specimens used in the present work were prepared from the composite consisting of 2.5 mm tantalum plate (99.87 wt. %) explosively welded to 8.0 mm steel plate with 0.20 wt. % carbon. The samples were sealed in the quartz capsule with 0.3 bar argon, annealed at 1 053 K for 112 h in the GK—2B—type diffusion furnace. The temperature was controlled with a thyristor regulator and was found to be within ±1 °C as measured with a calibrated Ni-Cr/Ni-Al thermocouple. After the heat treatment, the
samples were quenched into water by breaking the capsule. The quenched specimens were ground, polished parallel to the diffusion direction and etched in an aqueous alcohol solution containing 3% nitric acid. The samples were then investigated using an optical microscope (POLYVAR-MET) and electron microprobe analysis (X-650 and JEOL Superprobe 733).

2 RESULTS AND DISCUSSION

From the Fe-Ta, Ta-C and Fe-C binary phase diagrams, we constructed a tentative isothermal section of the Fe-Ta-C system at 1053 K, which is given in Fig. 1. The microstructure that developed in the tantalum-steel explosion weld interface after 112 h annealing at 1053 K is shown in Fig. 2. The phase regions in the microstructure were as follows: (1) the original steel endmember at the top of the micrograph, identified with γ-Fe and α-Fe; (2) an intermetallic compound layer morphology formed adjacent to the steel; (3) the original tantalum on the bottom of the micrograph, designated by α-Ta. The phases within the microstructure shown in Fig. 2 were analyzed using an electron microprobe technique and the composition is summarized in Table 1. The concentration profile was obtained from the tantalum-steel couple using a number of microprobe scans across different portions of the bond zone. A trace from the tantalum-steel interface at 1053 K for 112 h is shown in Fig. 3. Each microstructural phase found is identified in the composition profile. In the profile, the γ-Fe and α-Fe region on the left-hand side of the composition profile corresponds to the profile within the steel endmember, and the α-Ta region on the right-hand side of the profile is the original tantalum endmember. The carbide layer in Fig. 2 which was identified by electron probe microanalysis (EPMA) is the Ta₂C phase (Fig. 1). According to the optical micrograph in Fig. 2 and the composition range of each phase, as determined by EPMA, the diffusion path at 1053 K which goes through the γ-Fe, α-Fe, Ta₂C and α-Ta phase regions is plotted in Fig. 1.