§21. Development of Disimilar Welding with Low Activation Structural Materials

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1. Introduction

Vanadium (V) alloy is recognized as a promising low activation structural material for advanced fusion reactor blanket because of its good high temperature strength and resistance to neutron irradiation. The self-cooled liquid-lithium (SCLL) blanket is one of the blanket design using the V-alloy as a structural material. Since the peripheral component of the SCLL blanket such as the heat exchanger will be fabricated using austenitic stainless steel, the joining technology with those materials should be developed. The objective of this study is to investigate the hardness distribution in the dissimilar-material weld joint with the pure-V and austenitic stainless steel and the effect of post welding heat treatment (PWHT) in order to estimate the fundamental properties of dissimilar-material weld joint with the V-alloys and austenitic stainless steel.

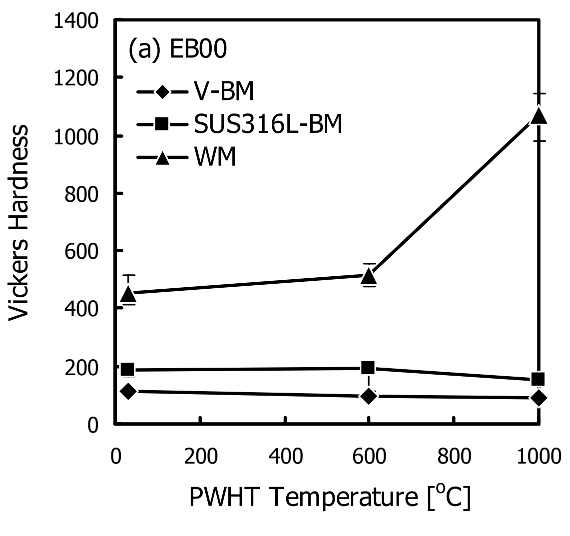
2. Experimental

Pure-V and SUS316L austenitic stainless steel were employed for the welding. Electron beam butt-welding was carried out in vacuum using flat plates in dimension of 50 mm × 50 mm × 4 mm. The acceleration voltage, the beam current and the welding speed were 150 kV, 12 mA and 1000 mm/min, respectively. The electron beam was positioned just on the butt joint (EB00), shifted by 0.2 mm (EB02) and 0.4 mm (EB04) on the pure-V side to evaluate the effect of melting behavior of Fe, Cr and Ni, which might affect the solution hardening and precipitation hardening of weld region. The PWHT was performed in vacuum at 600°C and 1000°C for 1 h. Vickers hardness measurement and the microstructural and compositional analysis were performed before and after the PWHT.

3. Results

The EBW joint was distinguished into four regions, which were the base metal of V (V-BM), weld metal (WM), interlayer at the edge of the WM of SUS316L side (IL) and base metal of SUS316L (SUS316L-BM). The IL was observed only in the EB02 and EB04 joints. No significant defects were observed in the EB00 and EB02 joints, whereas the formation of macro-pores was observed at the top and bottom region of the EB04 joint. Much higher hardness (Hv450–Hv500) was observed at the WM and IL of the as-welded EB00 and EB02 joints than the other regions. It was possible that the solution hardening occurred in the WM of these joints.

The PWHT temperature dependence of hardness in V-BM, WM, IL and SUS316L-BM for the EB00 and EB02 joints is summarized in Fig. 1. Almost no change of the hardness in SUS316L-BM and V-BM was observed both in the EB00 and EB02 joints. The hardness change in the WM was relatively small due to the PWHT at 600°C up to 1 h, whereas significant increment was observed due to the PWHT at 1000°C for 1 h regardless of the EB position. The hardness of the IL of the EB02 joint after the PWHT at 600°C was about Hv1000, which was almost twice higher than that of the as-welded one. The IL showed slight increment of the hardness due to the PWHT at 1000°C as compared to that at 600°C. Based on EDS analysis result and the phase diagram of Fe-V and Ni-V binary systems, the formation of σ-phase of the Fe-V system and V_3Ni in the WM and IL of the EB00 and EB02 joints was considered. Therefore, it was possible that the formation and growth of the σ-phase and V_3Ni precipitate due to the PWHT affected the hardening.



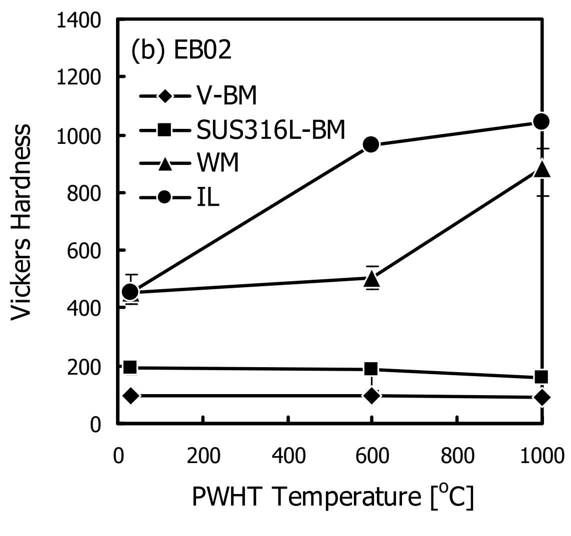


Fig. 1 The PWHT temperature dependence of hardness in V-BM, WM, IL and SUS316L-BM for the (a) EB00 and (b) EB02 joints (PWHT: 600°C and 1000°C for 1 h)