§12. Effect of Li on the Mechanical and Corrosion Properties of V-4Ti-4Cr Alloy

Tsisar, V., Nagasaka, T., Muroga, T.

Introduction

"V-4Ti-4Cr alloy – liquid Li" system is one of the most attractive blanket concepts [1]. The character of corrosion interaction in this system lies mainly in the redistribution of non-metallic impurities (C, O, N, H) between solid metal and melt [2]. Welding also resulted in the redistribution of O between precipitates (Ti-C,O,N) and solid solution in weld metal. In this work the effect of NMI on the mechanical and corrosion properties of electron beam welds (EB) of V-4Ti-4Cr alloy (NIFS-HEAT-2) was investigated.

Experimental

Three types of samples were manufactured: tensile (5×1.2×0.25 mm); coupon (20×4×1.5 mm) and Charpy impact specimens (3.3×3.3×25.4 mm). The latter two groups of samples with EB welds were machined from 4 mm thick plate of V-alloy. The bead-on-plate EB welding (1.5 kW) was carried out under high vacuum atmosphere in SFC Co., Ltd. (Yokohama, Japan). A V-notch (0.66 mm in depth, angle of 30° and root radius of 0.08 mm) was placed in the weld metal (WM) perpendicular to the rolling direction. Corrosion tests were carried out in static Li at 700°C for 100, 250 and 500 h using V-5Ti capsule.

Results

Coarse-grained columnar crystallites were formed in Weld Metal (WM) after welding [Fig. 1]. Thickness of WM does not exceed 1 mm. Hardness of WM averaged 180 kg/mm^2 while hardness of Base Metal (BM) was about 135 kg/mm^2. It is caused by decomposition of Ti-CON precipitates during welding procedure followed by the solid-solution hardening of V-matrix with O. The determined phase-structural features of WM, HAZ and BM are typical for V-alloy weld joins and are in a good accordance with the previous results [3].

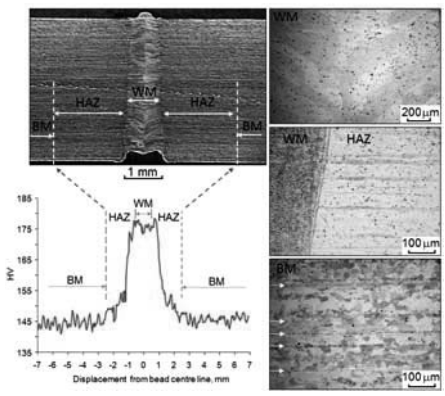

Fig. 1. Morphology and hardness profile of EB weld of V-4Ti-4Cr versus welding zones: weld metal (WM), heat affected zone (HAZ) and base metal (BM).

For samples exposed to Li the cleaning procedure in 30%H_2O_2 solution was developed and successfully applied to mitigate hydrogenation of V-4Ti-4Cr alloy taking place during cleaning in water, anhydrous ammonia and ethanol.

Vickers hardness profiles measured on the cross-sections of samples indicated about nitrogen uptake by V-alloy from Li during test which resulted in the formation of hardened zone (1000 kg/mm^2, ~70 μm).

The character of load-displacement curves and fracture surface of samples after PWHT at 973 K and after exposure to Li at 973 K were similar but differ substantially from those of sample in as-welded condition (Fig. 2). PWHT at 973 K and after exposure to Li at 973 K resulted in the brittle fracture of WM during impact test at 77 K while in as-welded condition it demonstrated ductile fracture accompanied by substantial lateral expansion. The absorbed energy of the latter one calculated as an area under load-displacement curve was about four times higher (9.5 J) in comparison with these after PWHT (2.2 J) and Li exposure (1.8 J) at 973 K. The marked difference can be attributed to the different phase structural state of WM.

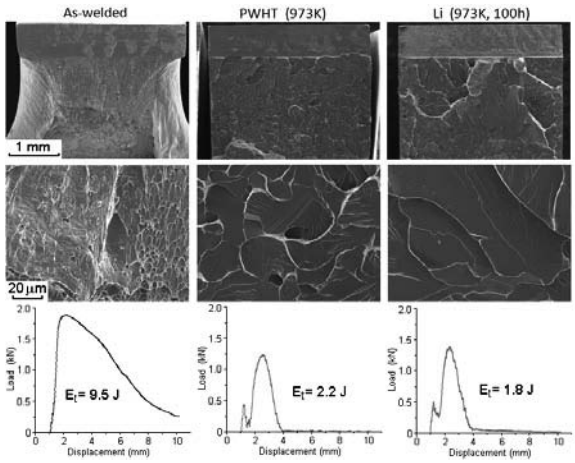

Fig. 2. Fractography and corresponding load-displacement curves of V-4Ti-4Cr alloy obtained after impact test at 77 K depending on pre-treatment: as-welded conditions; after PWHT at 973 K and after exposure to Li at 973 K.

It was concluded that: ► Charpy impact properties (77 K) of weld metal remains high enough in as-welded conditions in spite of the solid-solution hardening by O ► Charpy impact properties (77 K) of weld metal were degraded by the precipitation-assisted hardening caused by PWHT at 973 K and exposure to liquid Li at 973 K ► Inferior influence of N impurity present in the liquid Li on the mechanical properties of V-alloy was confirmed ► Cleaning in 30%H_2O_2 solution mitigates hydrogenation of V-4Ti-4Cr alloy exposed to Li.

Results of the work were presented at "2nd JOINT IAEA - EC TOPICAL MEETING" Ispra (Italy) 16-20 April 2012.

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[2] K. Natesan, J. Nucl. Mater. 115 (1983) 251–262.
[3] T. Nagasaka, Nam-Jin Heo, T. Muroga, A. Nishimura, H. Watanabe, M. Narui, K. Shinozaki, J. Nucl. Mater. 329–333 (2004) 1539–1543.