Different Properties of HT9 Steel as an Endcap Welding Material of Nuclear Fuel Cladding Tube

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1. Introduction

Korea Atomic Energy Research Institute (KAERI) are planning to use a high chromium ferritic/martensitic HT9 steel as an endcap welding materials of a nuclear fuel cladding tube in sodium-cooled fast reactor (SFR) due to high temperature properties of the HT9 steel. In order to enhance welding properties, Laser and tungsten-inert-gas (TIG) welding are considered for the method of the endcap welding. The HT9 steel weldments were heat treated in order to improve mechanical properties.

Samples with post-weld heat treatment (PWHT) after laser and TIG welding were compared to examine microstructure and a mechanical property.

1.1 Welding Methods

Various welding processes are now available for the end plug closure of a nuclear fuel element such as gas tungsten arc welding (GTAW), resistance welding (RW), electron beam welding (EBW), magnetic resistance welding (MRW), and laser beam welding (LBW).

1.2 HT9 Weldment Microstructure

Martensite formation in three areas of an HT9 weldment causes concern over the weld's integrity. These three areas, or zones, of the weldment are indentified as the fusion zone, heat affected zone (HAZ) and base metal.

2. Experimental Procedures

9Cr steel for SFR fuel cladding was selected for this study. The chemical compositions of the steels are given in Table 1 and GTAW conditions applied are summarized in Table 2.

Microstructures of before and after PWHT samples were measured by scanning electron microscope (SEM) and transmission electron microscope (TEM) to demonstrate differences of phase formation and precipitation between two different weldments. The crystalline structures of before and after PWHT samples were characterized by X-ray diffractometer (XRD) in order to identify the resulting phases after PWHT. Mechanical properties of specimens were investigated by Vickers micro-hardness test. In this study, endcap of the nuclear fuel cladding tube was successfully joined via Laser and TIG welding and effects of the PWHT of weldments on the microstructures and mechanical properties are discussed.

Table 1. Chemical compositions of steels (wt%)

	C	Cr	Mo	B	N	Ta
M1	0.07	8.89	0.44	0.013	0.020	0.04
M2	0.06	9.09	0.45	0.004	0.077	0.04

Table 2. GTAW conditions

Welding clearance	Voltage (V)	8
	Stick-out (mm)	0.7
Rotation angle	Total (°)	2000
	Rotational speed (rpm)	30
	Start (°)	20
	End (°)	460
Welding current (A)		30

3. Results and Discussion

Microstructures of before PWHT samples were measured by scanning electron microscopy (SEM) are given in Fig. 1 and Fig. 2. Included in these Figures are longitudinal sections of each weld taken at 500x magnification and of each weld's HAZ taken at 1500x magnification.

Mechanical properties of specimens were investigated by Vickers micro-hardness test are given in Fig. 3. Hardness testing can be used to indicate the degree of tempering experienced by a martensitic structure; the hardness in the structure is related to the amount of carbon retained in solution.

4. Conclusions

This study was carried out to determine the proper GTAW conditions. The hardness profiles in Fig. 3, showing hardness values at different locations in the weld specimens, all consistently indicate a drop in hardness relative to adjacent points near.

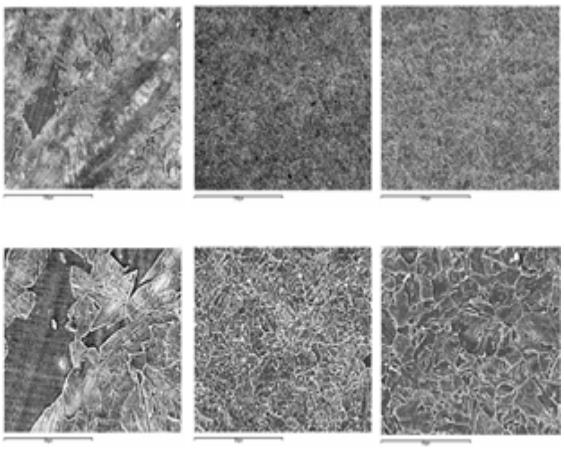

Fig. 1. Scanning electron microscopy (SEM) HT9M1: (a) weld metal (x500), (b) HAZ (x500), (c) base metal (x500), (d) weld metal (x1500), (e) HAZ (x1500), and (f) base metal (x1500).

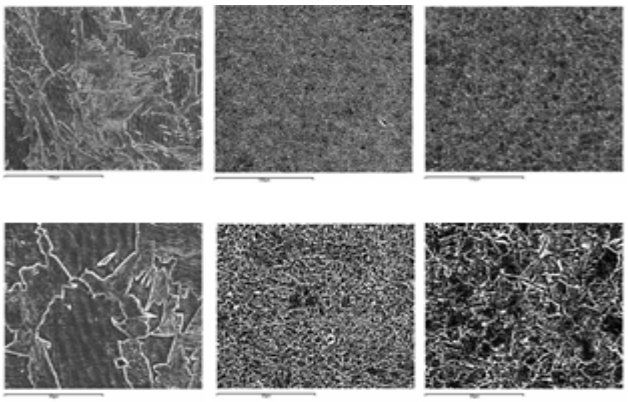

Fig. 2. Scanning electron microscopy (SEM) HT9M2: (a) weld metal (x500), (b) HAZ (x500), (c) base metal (x500), (d) weld metal (x1500), (e) HAZ (x1500), and (f) base metal (x1500).

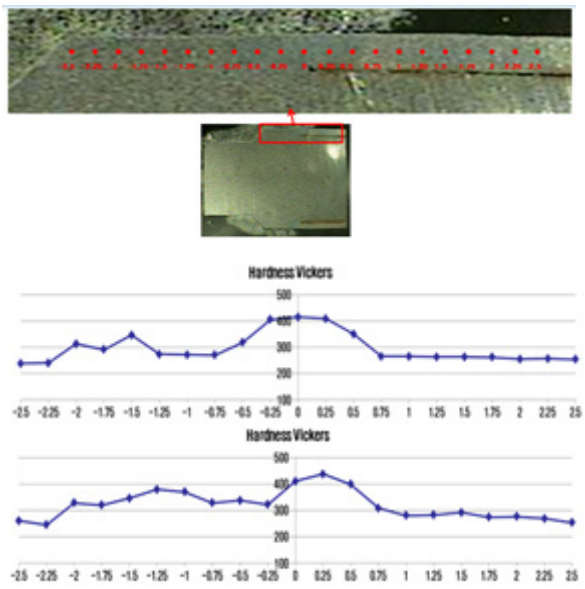

Fig. 3. Vickers micro-hardness test. (a) HT9M1 and (b) HT9M2.

5. REFERENCES

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