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Development of GTAW Repair process for CRDM Welds on Reactor Vessel Head

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1. Introduction

As a result of the Alloy 600 PWSCC(Primary Water Stress Corrosion Cracking), leak in the CRDM(Control Rod Drive Mechanism) nozzles was discovered at the Oconee Nuclear Station 3 and other PWR(Pressurized Water Reactor) facilities. The leaks occur at the pressure-retaining boundary which includes the CRDM J-groove welds and the region of the nozzle internal wall. The purpose of this research is to develop the repair welding process for j-groove welds with the defects. We developed equipment for the j-groove repair welding, applied Procedure Qualification for the repair welding process and investigated a bead shape, macrostructure and microstructure of welded specimen.

2. Welding Manipulator

Figure 1 shows a repair welding manipulator for j-groove welds. The developed equipment has 4 axes. The peripheral tools have 3D laser vision sensor, CCD camera, temperature sensor etc. The 3D laser vision sensor has a function of the control of position and the creation of welding pass. The GTAW(Gas Tungsten Arc Welding) process was used as a welding method.

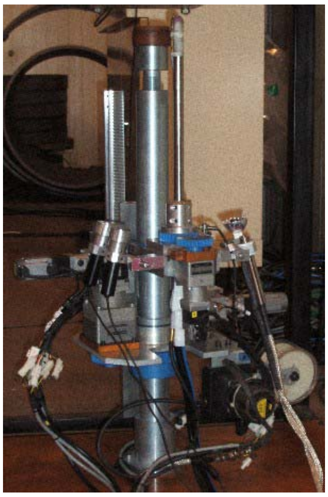


Figure 1. Repair welding manipulator for j-groove welds

3. Experiment & Results

3.1 Experiment method

The base and the filler materials were SA508 Grade3 Class1 and ERNiCrFe-7(alloy152) respectively. The chemical compositions of the base and the filler materials are shown in table 1 and 2. The conditions of welding parameters are shown in table 3.

The GTAW was used as the repair welding process and the welding position was overhead.

Table. 1 The chemical compositions of base material.

Element	C	Mn	P	S	Si
Wt %	~0.25	1.2 ~1.5	~0.025	~0.025	0.15 ~0.4
Element	Ni	Cr	Mo	Va	Fe
Wt %	0.4 ~1.0	~0.25	0.45 ~0.6	~0.05	Rem.

Table. 2 The chemical compositions of filler material.

Element	Mn	Fe	P	S	Si
Wt %	~1.0	7.0 ~11.0	~0.02	~0.015	~0.5
Element	Al	Ti	Cr	Etc	Ni
Wt %	~1.1	~1.0	28 ~31.5	~0.6	Rem.

Table. 3 The welding conditions.

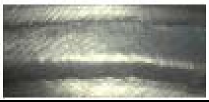
Process	GTAW	Shield gas	Ar, 18*l*/min
Polarity	DCEN	Gas cup	12mm
Electrode	2.4mm, EWTh-2	Position	Overhead
Frequency	2.8	Duty	0.4
Welding speed	160~180 mm/min	Wire feeding rate	900 ~ 1,300 mm/min

※ DCEN : Direct Current Electrode Negative
※ EWTh-2 : 2% Thorium Tungsten Electrode (AWS A5.12)

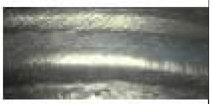
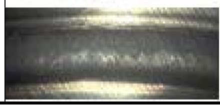
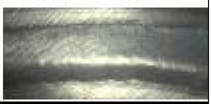
3.2 Results

Figure 2 and 3 show the bead shape and the macrostructure after welding. When the welding current and the wire feeding rate were constant, the bead shape was better as the welding speed was higher (Figure 2, (a)). When the welding current and the welding speed were constant, the bead shape was better as the wire feeding rate was higher (Figure 2, (b)). The macrostructures after welding were good shape in the all conditions(Figure 3). From these experiments, we adopted the optimum welding conditions which were peak current(140A), base current(70A), welding speed(180mm/min) and wire feeding rate(1,100mm/min). Figure 4 shows the microstructure after welding with these conditions.

After that, we accomplished the PQ(Procedure Qualification, ASME SEC. IX) with the optimum welding conditions and the good results.

Peak Current		150A	
Base Current		70A	80A
Welding speed [mm/min]	160		
	180		
	200		

(a) The wire feeding rate : 1,100mm/min

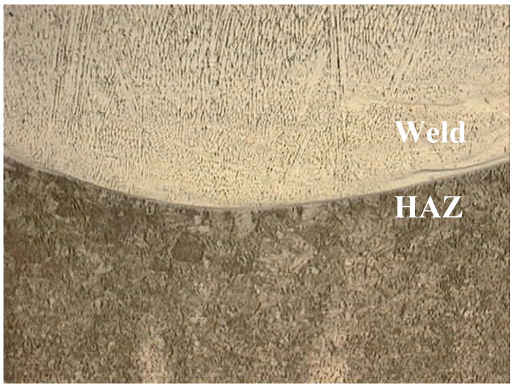
Peak Current		150A	
Base Current		70A	80A
Wire feeding rate [mm/min]	900		
	1100		
	1300		

(b)The welding speed : 180mm/min

Figure 2. Bead shape after welding with developed equipment

Peak Current		150A	
Base Current		70A	80A
Welding speed [mm/min]	160		
	180		
	200		

Figure 3. Macrostructure after welding with developed equipment (Wire feeding rate : 1100mm/min)



- Figure 4. Microstructure after welding with developed equipment(peak current : 140A, base current : 70A, welding speed : 180mm/min and wire feeding rate : 1,100mm/min)

4. Conclusions

We have developed a repair welding manipulator for j-groove welds defects and established the optimum welding process. The results are as following.

- Welding position : Overhead
- Welding condition : peak current 140A, base current 70A, welding speed 180mm/min, wire feeding 1,100mm/min
- PQ results : Accepted

REFERENCES

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[2] Charles R. Frye, Melvin L. Arey, Michael R, Robinson E. Whitaker, Evaluation and Repair of Primary Water Stress Corrosion Cracking in Alloy 600/182 Control Rod Drive Mechanism Nozzles, ICONE 10, 2002.

[3] Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique, ASME Code, Case N-638.