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WELDABILITY EVALUATION OF THICK SECTIONS OF HASTELLOY X WITH VARYING ALUMINUM CONTENT

NERVA PROGRAM CONTRACT SNP-1

NUCLEAR ROCKET OPERATIONS

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AEROJET-GENERAL CORPORATION

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RN-S-0519

WELDABILITY EVALUATION OF THICK SECTIONS OF HASTELLOY X WITH VARYING ALUMINUM CONTENT

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ABSTRACT

Hot cracking and poor wetability of the molten weld metal presented problems in welding the thick sections of the Hastelloy X Phoebus 2 nozzle. A program was conducted to evaluate the effect of varying percentages of aluminum on the weldability of Hastelloy X. The results indicate that lowering the aluminum content of Hastelloy X improves weldability. Utilization of the low-aluminum Hastellcy X material for the NERVA nozzle should result in improved weld quality and lower welding costs.

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I. INTRODUCTION

Additions of aluminum which exceed the critical tolerance to fix gas reactions may induce weld hot cracking in nickel base alloys.* Hot cracking and poor wetability of the molten weld metal presented problems in welding the thick sections of the Hastelloy X Phoebus 2 nozzle. The Phoebus nozzle material and weld wire residual aluminum content was in the range of 0.25 to 0.35 percent, with 0.500 percent being the maximum allowed by the material specification. The aluminum forms a stable oxide which inhibits wetability and deposits oxides on the weld surface.

II. OBJECTIVE

The objective of this program was to evaluate the effect of varying percentages of aluminum on the weldability of Hastelloy X.

III. SUMMARY

Four 1-in. thick plates (representing four material heats with varying aluminum compositions) were procured to accomplish the evaluation. Aluminum content of the plates varied from 0.540 percent to 0.010 percent. All heats were vacuum-induction melted with one heat (ESR-68-603) being remelted by the electro-slag process. Hastelloy X weld-wire from two material heats (with aluminum content varying from 0.210 percent to 0.048 percent) was used to accomplish the welding. Material heat numbers and chemical analysis of the plates and weld wire are shown in Table 1. Weld preparation for all plates consisted of a double U-groove with a 60 deg included angle and a 0.050/0.060 root land. The plates were welded by the semi-automatic gas tungsten arc process (GTAW) under controlled conditions with such variables as amperage, voltage, wire-feeds, weld travel-speed, and shielding gas-flows remaining the same for each weldment. Welding conditions were as follows:

*Welding Handbook - Sec. 1, Chapter 2, Page 2.83; Sec 4, Chapter 67, Pages 67.2, 67.3, 67.39.

Amps	Volts	Travel Speed	Wire Feed	Shielding Gas Mixture and Flow Rate
215	9.5	5 in. per min.	30 in. per min.	50% He, - 50% A at 50 C. F. H.

An evaluation of the weldability characteristics of each plate was made by visual observation of the wetability, molten-pool cleanliness, and weld-surface characteristics. The Hastelloy X Phoebus-2 nozzle welding experience was used as a standard of comparison in making the evaluation.

IV. CONCLUSIONS

Oxide content and metal flow of TIG process welds are improved by reducing the Al content of Hastelloy X to 0.01%. There is some indication that the Al content of filler wire is more significant than that of the parent metal.

TABLE 1

CHEMICAL ANALYSIS OF PLATES AND WELD WIRE OF SEVERAL HEATS

Chemical Composition by Percentage

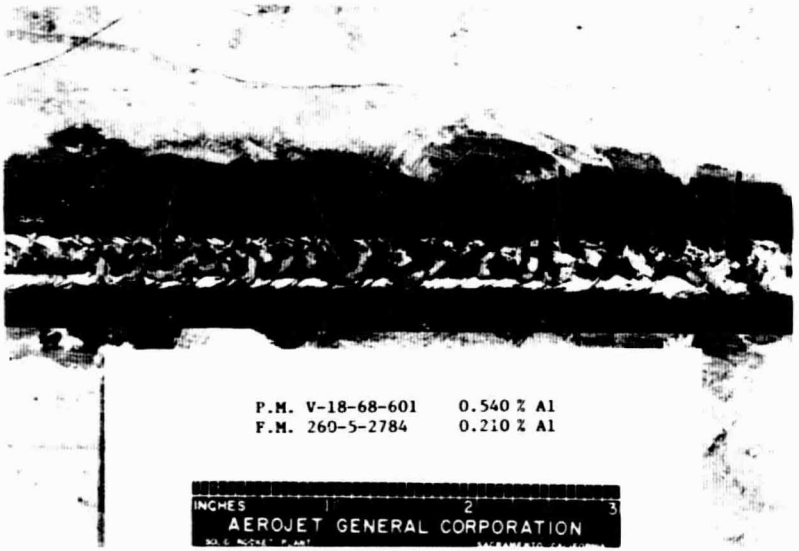
Heat No.	Cr	W	Fe	C	Si	Co	Ni	Mn	B	V	Mo	Cu	P	S	Zr	Al	Ti	Ca	Mg	Pb
V-18-68-601	22.43	0.56	18.56	0.08	0.64	1.57	45.65	0.89	0.001	0.01	9.10	0.02	0.002	0.009	0.003	0.540*	0.015	0.010	0.014	0.0010
ESR-68-603	22.70	0.54	18.54	0.09	0.46	1.59	44.65	0.95	0.001	0.02	9.18	0.03	0.010	0.006	0.001	0.660*	0.002	0.010	0.013	0.0010
V-22-68-632	22.15	0.53	18.60	0.07	0.56	1.84	46.53	0.72	0.001	0.01	8.9	0.02	0.001	0.007	0.002	0.270*	0.010			
V-19-68-617	22.63	0.55	19.04	0.07	0.59	1.63	43.80	1.05	0.001	0.01	9.19	0.03	0.007	0.011	0.001	0.010*	0.002	0.010	0.014	0.0010
WELD WIRE																				
260-5-2784	21 30	0.51	18.47	0.09	0.18	1.90	47.60	0.64	0.002	0.02	9.03	0.04	0.020	0.009		0.210*	0.03			
2610-7-2203	21.45	0.46	17.45	0.08	0.28	1.63	48.85	0.67	0.001		9.13		0.001	0.008	0.01	0.048*	0.01			

*Ledoux laboratory analysis

TABLE 2

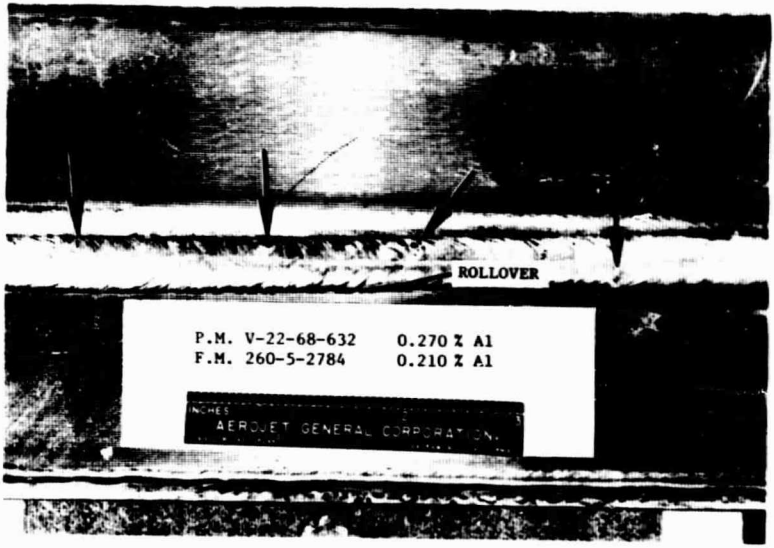
WELDABILITY EVALUATION

Heat No.	Alum. %	Heat No.	Alum. %	Weld Photo	Weldability Characteristics
					High Aluminum Base Plate - High Aluminum Filler
V-18-68-601	0.540	260-5-2784	0.210	Figure 1	Weldability was significantly impaired by the heavy oxide formations. Wetability was poor and the surface of the completed weld bead was covered with a heavy oxide that obscured the normal weld ripple pattern.
					Intermediate Aluminum Base Plate - High Aluminum Filler
V-22-68-632	0.270	260-5-2784	0.210	Figure 2	Weldability was better than plate 68-601. However, oxide formations were evident which inhibit the flow of the molten metal and, instead of feathering at the weld edge, the molten metal tends to roll over. Oxide was evident on the completed weld. mostly along edge of the weld bead.
					Low Aluminum Base Plate - High Aluminum Filler
ESR-68-603	0.060	260-5-2784	0.210	Figure 3	An example of the adverse effect of high Al content filler wire on weldability characteristics. Note scattered oxides on weld surface.
					Low Aluminum Base Plate - High Aluminum Filler
V-19-68-617	0.010	260-5-2784	0.210	Figure 4	The high Al content wire definitely reduced the good weldability characteristics. The molten pool contained oxides and the wetability was somewhat impaired. Scattered oxides were evident on the completed weld.
					Intermediate Aluminum Base Plate - Low Aluminum Filler
V-22-68-632	0.270	2610-7-2203	0.048	Figure 5	Cleanliness and improved fluidity of the molten pool was evident using the low aluminum filler wire. The surface of the completed weld exhibited a good ripple pattern and only one or two small oxide formations.
					Low Aluminum Base Plate - Low Aluminum Filler
V-19-68-617	0.010	2610-7-2203	0.048	Figure 6	Weldability was very good, the flow characteristics were optimum with excellent blending at the edges. The molten pool was clean and the completed weld exhibited a clean surface and a well-defined ripple pattern.



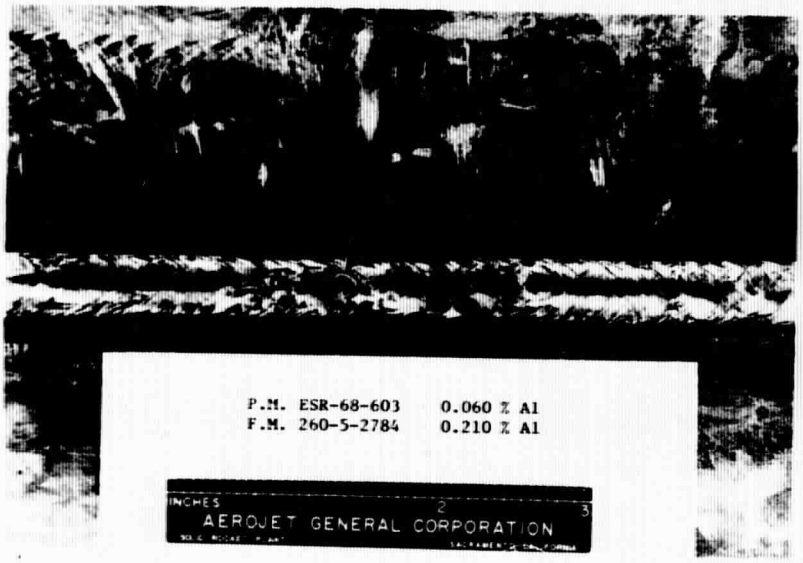
Weldability was significantly impaired by the heavy oxide formations. Wetability was poor and the surface of the completed weld bead was covered with a heavy oxide that obscured the normal weld ripple pattern. Typical oxide formation is indicated by the arrows.

Figure 1 - High Aluminum Base Plate - High Aluminum Filler



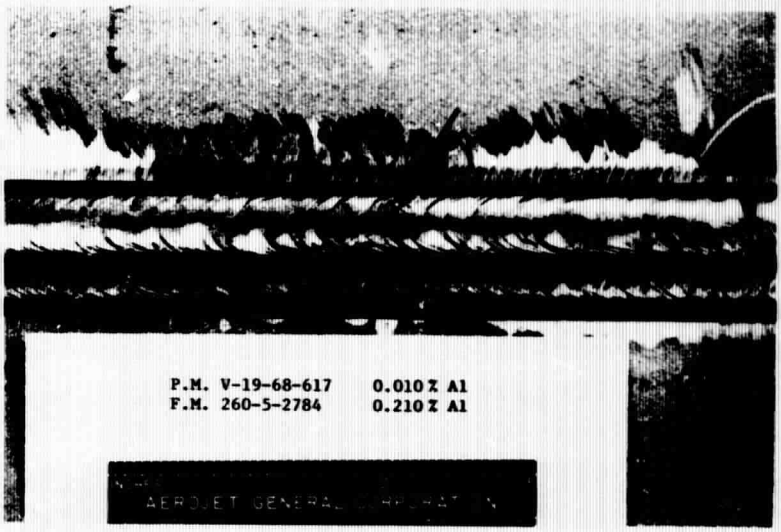
Weldability was better than plate 68-601. However oxide formations were evident which inhibit the flow of the molten metal and, instead of feathering at the weld edge, the molten metal tends to roll-over. This roll-over usually causes voids or lack of fusion in multiple-pass welds. Oxide was evident on the completed weld, mostly along edge of the weld bead. Typical oxide formation is indicated by the arrows.

Figure 2 - Intermediate Aluminum Base Plate - High Aluminum Filler



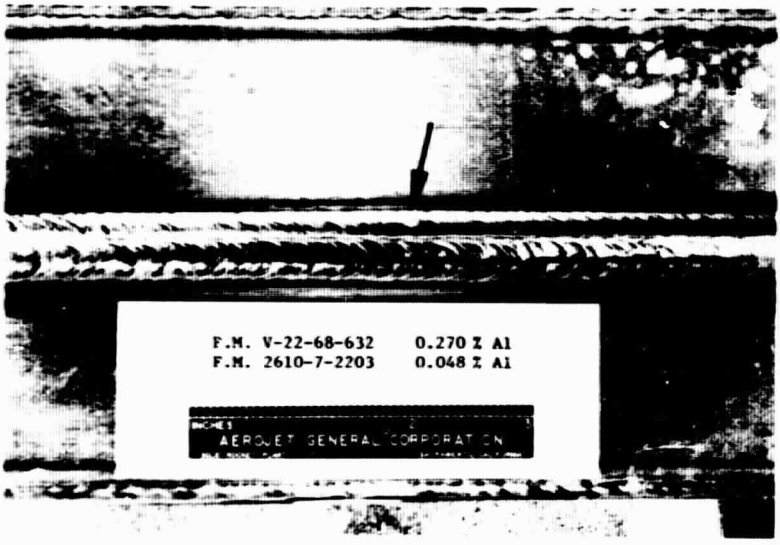
An example of the adverse effect of high Al content filler wire on weldability characteristics. Note scattered oxides on weld surface. Typical oxide formation is indicated by the arrows.

Figure 3 - Low Aluminum Base Plate - High Aluminum Filler



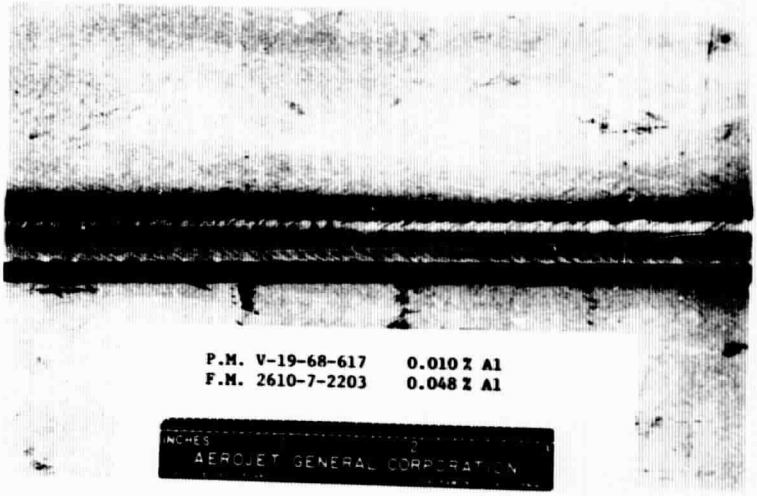
The high Al content wire definitely reduced the good weldability characteristics. The molten pool contained oxides and the wetability was somewhat impaired. Scattered oxides were evident on the completed weld. Typical oxide formation is indicated by the arrows.

Figure 4 - Low Aluminum Base Plate - High Aluminum Content Filler



Cleanliness and improved fluidity of the molten pool was evident using the low aluminum filler wire. The surface of the completed weld exhibited a good ripple pattern and only one or two small oxide formations. Typical oxide formation is indicated by the arrow.

Figure 5 - Intermediate Aluminum Base Plate - Low Aluminum Filler



Weldability was very good, the flow characteristics were optimum with excellent blending at the edges. The molten pool was clean and the completed weld exhibited a clean surface and a well-defined ripple pattern.

Figure 6 - Low Aluminum Base Plate - Low Aluminum Filler