A Welding Defect Related to the Aluminum Content in a Nickel-Base Alloy

The aluminum content of parent metal can be critical where very high weld integrity is required in applications involving thin gages of nickel-base alloys

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ABSTRACT. A problem associated with welding the middle capsule of the Prototype Cardiac Pacemaker radioisotopic heat source resulted in a 17% rejection rate during production. It was established that it is possible for a drossy, aluminum-based material to exist along the grain boundaries in the weld metal of thin-gage Hastelloy C-276 when the parent material has aluminum concentrations equal to or greater than 0.2%. This drossy material can result in the welds failing to pass helium leak inspections under certain conditions.

Introduction

A problem associated with welding the middle capsule of the Prototype Cardiac Pacemaker radioisotopic heat source resulted in a 17% rejection rate during production. This problem occurred after changing the nominal 0.017 in. thick capsule material from Hastelloy® C (Hastelloy is a registered trademark of the Cabot Corp.) to Hastelloy C-276. The nickel-base alloys Hastelloy C and Hastelloy C-276 have essentially the same chemical composition (16% Cr, 16% Mo, 4% W, 5% Fe) with the exception that the carbon and silicon content of the C-276 is kept lower, primarily to enhance its corrosion resistance.

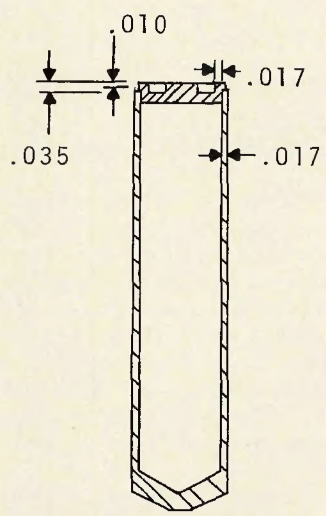

Fig. 1—Middle capsule weld joint details. Scale: 4X

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The Weld

The middle capsules were gas tungsten-arc (GTA) welded in an argon atmosphere. The major weld joint details are shown in Fig. 1. The major welding parameters were:

1) Electrode, 0.040 in. diameter 2% thoriated tungsten
2) Arc gap, 0.025 in.
3) Welding current, 16 ± 2 amp dcsp
4) Welding speed, 9.4 ipm

Evaluation

Out of a total of 46 welds, eight defective capsules were found with helium leak rates in excess of 1×10^{-5} std cm³/sec.

Metallographic examination of the Hastelloy C-276 welds revealed a drossy stringer material in the welds which had not been observed in the Hastelloy C welds. This foreign material was brittle and tended to "pull out" of the sample during polishing and it was partially dissolved by the oxalic acid etch.

Figures 2 and 3 are high and low magnification photomicrographs of two typical drossy areas in the polished and etched conditions respectively. The size and orientation of these defects varied from sample to sample and from location to location within a given sample. Additional metallography verified that a given drossy stringer had a three dimensional tortuous path through the sample, following various contiguous grain boundaries.

Chemical analyses of the Hastelloy C and Hastelloy C-276 confirmed they met the chemical composition requirements of the applicable AMS, ASTM and vendor specifications.

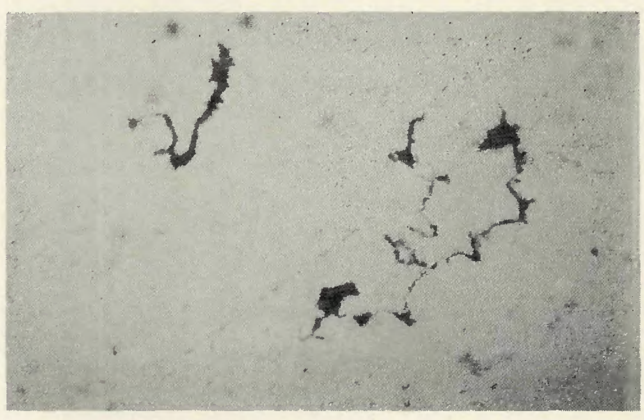

Fig. 2—Typical defect in Hastelloy C-276 weld; as polished; 550X

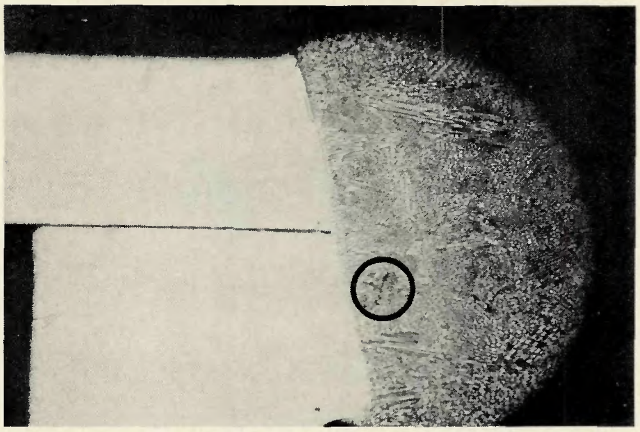

Fig. 3—Typical defect is Hastelloy C-276 weld; oxalic acid etch; 70X

Fig. 4—Aluminum concentration profile across a defect (trace at left)

A direct comparison of the chemical composition of the Hastelloy C and Hastelloy C-276 was performed by emission spectrographic analysis. This analysis included evaluating detectable elements not covered by the specifications. The most significant variation detected was that the Hastelloy C contained 0.05% aluminum while the Hastelloy C-276 contained from 0.2 to 0.3% aluminum. Additional investigation indicated that variations in aluminum content of this order for different heats may occur in both Hastelloy C and Hastelloy C-276.

Electron microprobe analyses of the defect areas were performed based upon the emission spectroscopy data. Aluminum based abrasives were not used during the preparation of these unetched samples. The microprobe analyses of the drossy areas indicated a depletion of the major elements nickel, chromium, molybdenum, iron, tungsten and cobalt and an enrichment of aluminum.

Figure 4 is a composite photograph showing the results of an aluminum analysis of one of the areas probed. The straight line across the defect area indicates the path of the electron beam while the trace to the left indicates relative aluminum concentration; deflection of this trace to the right indicates increased concentration. The available data suggests that the drossy material causing the defect areas is probably aluminum oxide (Al_2O_3).

This study has established that it is possible for an aluminum based material (probably Al_2O_3) to exist along the grain boundaries in the weld metal of thin gage Hastelloy C-276 when the parent material has aluminum concentrations equal to or greater than 0.2%.

The leaks in the eight middle capsules did occur when the size and orientation of the defects were such that they extended through the nominal 0.017 in. thick wall.

A similar dross problem has been observed in GTA welds made on 0.010 in. thick Inconel® 718 (Inconel is a registered trade mark of International Nickel Co.).

Conclusion

The aluminum content of the parent material can be critical where very high weld integrity is required in applications of thin gages of this or a similar alloy.

Acknowledgment

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