IRIDIUM WELDS ON SIMULANT FUEL CLADS, CHARACTERIZATIONS AND QUALIFICATION

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Introduction: Iridium welds performed to encapsulate plutonium 238 oxide fuel must be sound, and integrity and consistency of welds must be assured without undue consumption of iridium. Protocols for weld inspection are examined, and determined to be adequate to confirm consistency with historical welding operations. Evidence of repeatability and reliability among the welds inspected provides a basis for reliance on inspection frequencies and practises, to support current and future production of ^{238}Pu heat sources.

Heat sources are clad in iridium alloy containment vessels because of the advantageous properties of the alloy; inertness, hardness, strength, and high melting point. Vessels are welded using GTAW (Gas Tungsten Arc Welding) technology, under controlled and repeatable conditions. The integrity and strength of the weld provide critical protection against dispersal of plutonium oxide in accident scenarios. Accordingly, weld inspection comprises a critical part of the encapsulation process. Sample or Qualification Welds must be characterized periodically in order to ensure consistency between welds, and to assure the representative character of those selected welds which undergo destructive examination. However, the number of inspections must be minimized to reduce consumption of the costly iridium alloy clad bodies. Qualification Welds are prepared by welding a simulant rather than plutonium fuel into the iridium clad, and are characterized by several tests including metallographic examination. Verification of welds is key as production demands and budgetary constraints reduce the latitiude for frequent execution of Sample or Qualification Welds.

Experiment: Comparison of recently executed welds frecovered from simulant fuel clads suggests the range of weld morphologies that can be expected for these welds prepared under the controlled conditions imposed on the welder and the welding process. Variation in weld characteristics must be precluded, and consistency of product morphology assured in welding operations performed after different startups, on different days, and by different operators. Under robotic operation, parameters governing operation of the welder are closely controlled, as is the humidity and gas environment in the welder containment.

Recently executed welds were compared with extent records from previous welding campaigns made on the same welder. Images obtained from simulant clads produced for the Cassini mission and examples of post-Cassini welds were available from archival records, for comparison with recent data. Maintenance and repair has been performed on the welder between performance of these welds and current examples, activities which must be demonstrated to have produced no measurable change in weld characteristics. Data from independent studies of welds on iridium alloys are also available for comparison with recently executed welds. [1]

Results: Comparable microstructures were observed in the two modern welds, and also between the current examples and welds from previous welding campaigns. Grain counts were within the standard range of variation established during the Cassini mission, and grain elongation and morphology was similar in the modern welds to those from previous campaigns.

Iridium and alloys of iridium are prone to development of a columnar grain structure in the fusion zone of the weld, due to growth of crystallites along the preferred 100 axis. [1] This tendency is moderated by controlling composition to promote nucleation, and by carefully maintaining welding parameters to constrain the rate of crystallite growth in the fusion zone. [1] Use of a magnetic oscillator during welding changes the cooling rate, improving the microstructure and allowing formation of a refined grain structure. [2]

Metallography of modern welds indicates that grain counts and grain morphologies are similar to those of historical welds. Welds performed by different operators after independent startups separated by a moderate time interval are indistinguishable. All weld parameters are within specifications. Consistency between the several welds allows inference of microstructural parameters of the welds on fuel clads which cannot be destructively examined, and provides reassurance that welds are comparable, and that simulant clads provide adequate data for evaluation of all welds performed.

Based on data presented, control of welder parameters is deemed to be adequate to allow multiple welds to be performed between execution of sample welds destined for destructive examination. A substantial savings in costs and expenditure of parts is achieved. An increase in efficiency and speed of production is facilitated by increased confidence in weld integrity and quality.

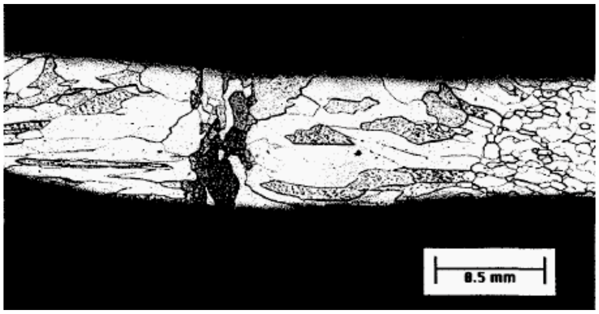

Figure 1. Iridium weld from Cassini mission welding campaign. Fusion, zone, heat affected zone, and original microstructure (right) clearly visible.

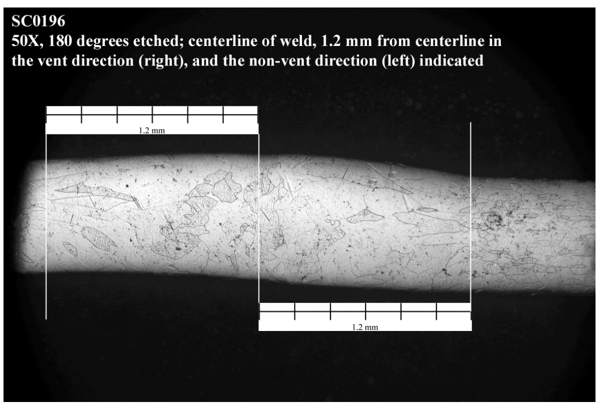

Figure 2. Iridium weld recently executed, showing grain refinement in fusion zone and extent of heat-affected zone comparable to historical example.

References:

[1] David, S.A., Ohriner, E.K., and King, J. F., (2000) "Welding and Weldability of Thorium-Doped Iridium Alloys," *www.osti.gov/bridge/product.biblio.jsp?osti_id=14972* [2] David, S.A., Babu, S.S., and Vityek, J.M., (2003) *JOM-J MIN MET MAT*. Vol. 55: 14-20.