AD/RHIC/RD-60

RHIC PROJECT

Brookhaven National Laboratory

RHIC Dipole Longitudinal Weld Evaluation

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Abstract

Metallographic analysis of the RHIC Dipole weld root revealed the presence of a void. A void in the weld root would serve as a notch in the most critically stressed area of the RHIC Dipole Coldmass. A BNL Cryogenic Safety Committee meeting attributed the void to the initial autogenous weld pass and suggested the addition of filler metal during this operation. Test samples were manufactured using the existing RHIC Dipole weld procedure and a modified procedure using filler metal for all operations. Longitudinal sectioning of the samples revealed a longitudinal void almost the entire length of the weld produced using the initial autogenous weld procedure. The specimen produced using the filler metal procedure resulted in a continuous weld with good fusion to the yoke.

Background

Metallurgical phase is critical to material mechanical properties at cryogenic temperatures, especially $4^{O}K$. The materials being used for the RHIC Dipole Coldmass are primarily austenite, with a small percentage of ferrite. Ferrite is detrimental to fracture toughness[1], but up to 3% can be accommodated. The RHIC Dipole Coldmass stainless steel shells are longitudinally welded to the Coldmass low carbon steel yoke. The BNL Cryogenic Safety Committee expressed concern about the ferrite number or ferrite percentage at the root of the longitudinal weld. The concern was that the steel yoke would significantly dilute the root passes, resulting in unacceptable ferrite numbers.

A. Ghosh conducted metallographic analysis[2] of the longitudinal weld cross-section to resolve the BNL Cryogenic Safety Committee concern. One of the metallographs revealed a void at the weld root. The cause of the void was not known. At a BNL Cryogenic Safety Committee meeting, A. Farland and C. Czajkowski postulated the void was caused by the initial autogenous weld pass. The gaps between the laminations may be interrupting the weld arc, resulting in discontinuity of the weld root. The addition of filler metal during this operation may eliminate the discontinuity.[3] The BNL Cryogenic Safety Committee recommended approval of the RHIC Dipole Coldmass design, pending qualification of the longitudinal weld procedure by Grumman. The Grumman procedure qualification was not expected for at least a year. A problem with weld qualification could adversely impact the RHIC Project, thus this evaluation was undertaken.

Procedure

A test specimen was prepared using pre-assembled, RHIC Dipole yoke blocks, consisting of 16 laminations and measuring approximately 105 mm (4.125"), and following RHIC Magnet Division Procedure RHIC-MAG-7340, RHIC Dipole Yoke/Shell Assembly. Shells were prepared with a 37^{o} bevel with a 0.76mm to 1.60mm (0.030" to 0.063") land using a hand grinder. The shells were locally cleaned with alcohol. Welding was performed by a certified welder using gas tungsten arc welding (GTAW); shield gas was 100% Argon. The root on one side was fused autogenously; this side was marked "N". The other side was welded using 1.6mm (1/16") diameter 308L filler wire and marked "W". The second shell was clamped to the yoke so the root spacing was equal on both sides at approximately 2.3mm (0.090"). Both welds were completed with three passes using 308L filler wire. The weld was then removed by cutting through the shells and yoke at the corners of the bus slot.

The shell and yoke were cut from outboard of the weld on one side of each specimen. The weld was then milled into the weld root, to within 0.25mm (0.010") of the opposite shell edge. The specimens were hand ground through a series if SiC papers starting with 240 grit, followed by 320 grit, 400 grit and finished with 600 grit. A lubricant of kerosene and paraffin was used. The specimens were cleaned in an ultrasonic cleaner using soapy water after each of these steps. Next, the specimens were polished using 6μ diamond paste and a nylon cloth on an 203mm (8") rotating wheel. The lubricant used was Buehler's Metadia Fluid, which is a solution of water and polypropylene glycol. The specimens were finally cleaned in the ultrasonic cleaner using water (no soap).

Results and Discussion

The specimen prepared using the autogenous initial fuse pass, Specimen "N", exhibited a void almost the entire length of the weld. The void was 1.33mm (0.052") at the widest point, just 4.13mm (0.1625") below the surface of the weld. This is shown in Figure 1. The shells measured 4.62mm (0.182"). The specimen prepared using 308L filler wire for all weld passes, Specimen "W", did not exhibit any voids. Fusion with the low carbon steel laminations was complete, with an average weld depth of 5.94mm (0.2335"), yielding a penetration of 1.32mm (0.0515"). This is shown in Figure 2.

The void running the length of the magnet longitudinal weld is clearly unacceptable. Paragraph QW-191.2.2, Acceptance Standards, Section IX, Welding and Brazing, of the ASME Boiler and Pressure Vessel Code, indicates that "any type of crack or zone of incomplete fusion or penetration" is unacceptable. Paragraph UW-35, Finished Longitudinal and Circumferential Joints, Section VIII, Division 1, Rules for Construction of Pressure Vessels, of the ASME Boiler and Pressure Vessel Code, states "Butt welded joints shall have complete penetration and full fusion." The reduction in cross-section will result in an 11% increase in weld stress, which is already at yield in the design.[4]

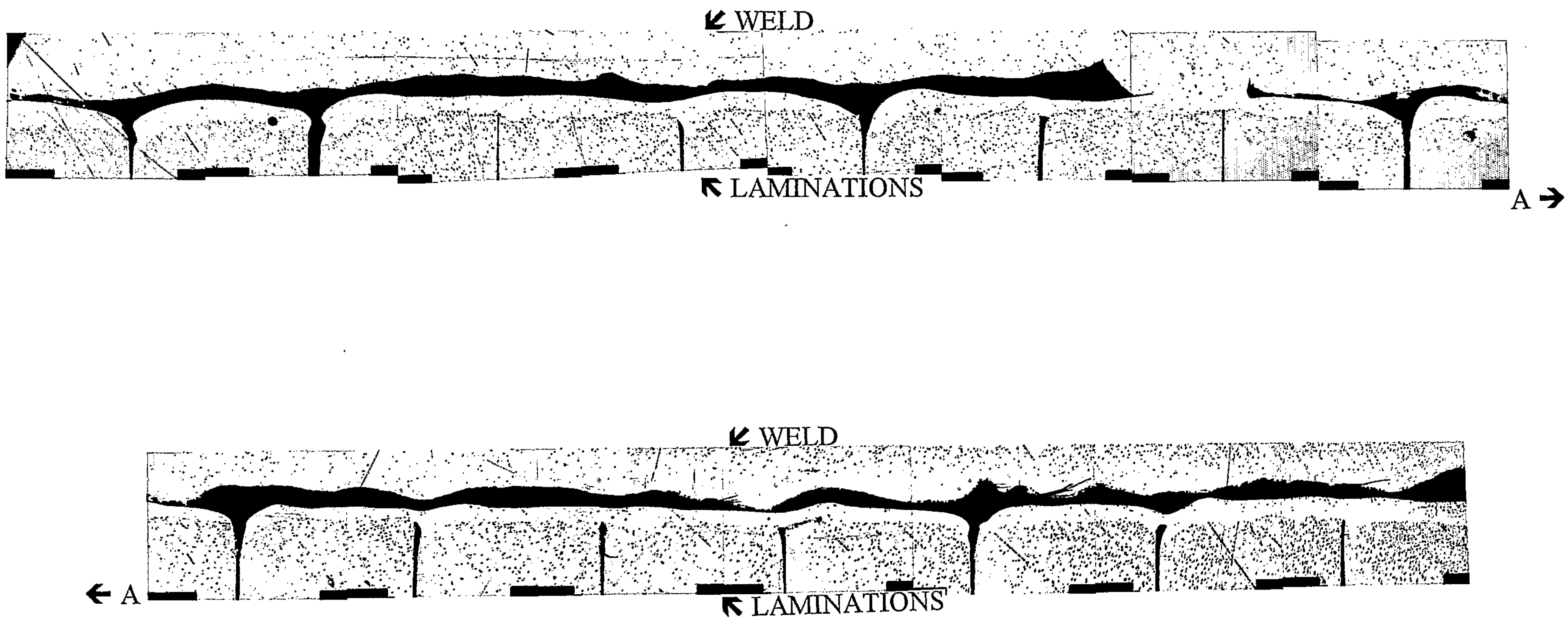

Figure 1. RHIC Dipole Longitudinal Weld Test Specimen "N", prepared using an initial autogenous root pass; 304L Shells welded using GTAW, 100% Argon Shield Gas, 1/16" diameter 308L Filler Wire. Dark area is a void.

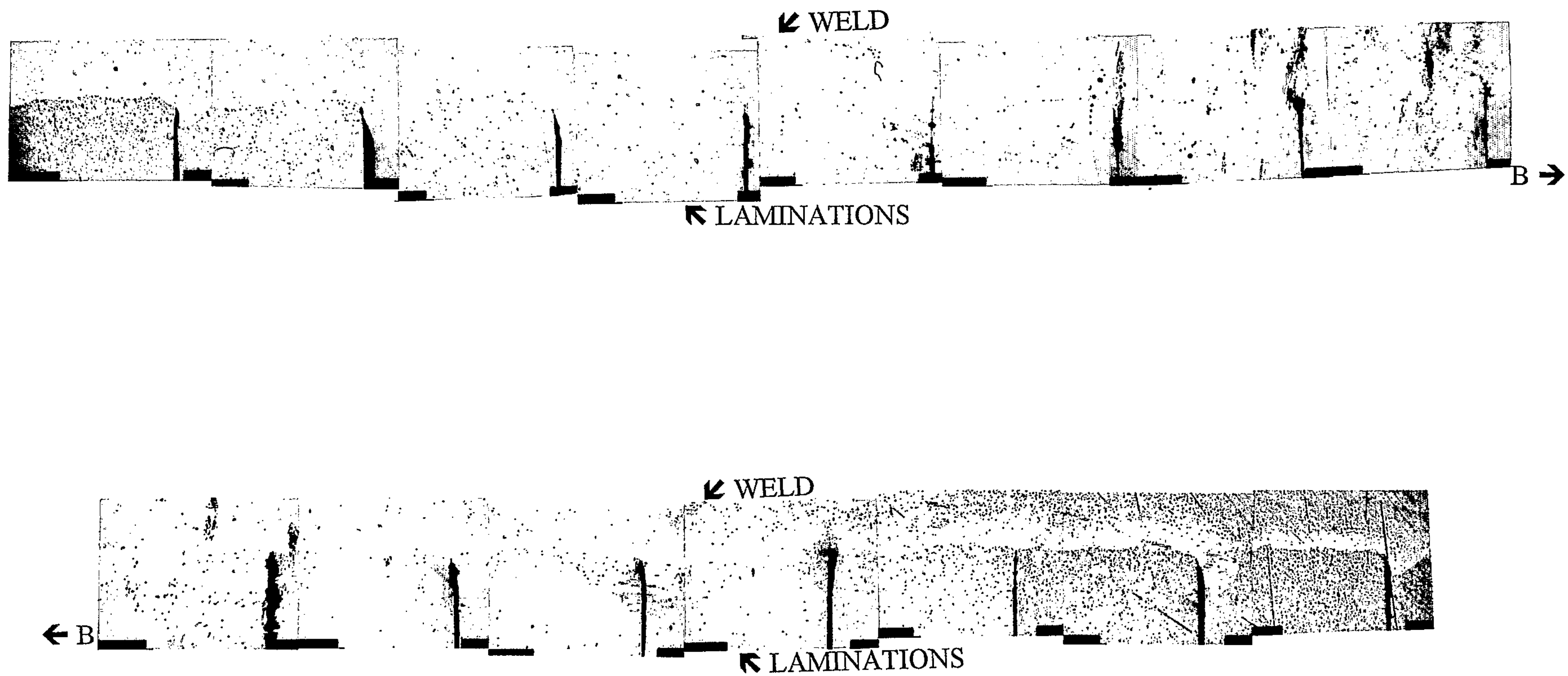

Figure 2. RHIC Dipole Longitudinal Weld Test Specimen "W", prepared using filler wire for all weld passes; 304L Shells welded using GTAW, 100% Argon Shield Gas, 1/16" diameter 308L Filler Wire

Conclusions

The addition of filler wire to the initial weld pass fills in the discontinuities along the yoke surface to be welded. This enhances arc stability and provides continuous fusion of the shells, and continuous fusion of the shells to the yoke.

[1] S. Kane; Fracture Toughness Requirements for RHIC Cryogenic Design, AD/RHIC/RD-40, May 1992
[2] A. Ghosh; Longitudinal Weld of the Stainless Steel Shell in the RHIC Dipole, Magnet Division Notes No. 478-16 (RHIC-MD-183), November 25,1992
[3] A.G. Prodell; BNL Cryogenic Safety Committee Meeting Minutes, 18 November 1992
[4]M. Lindner and S. Mulhall; Investigation of Azimuthal Stresses Due to Welding and Cooldown, Magnet Division Notes No. 419-7 (RHIC-MD-132), February 24, 1992