A.16: Study on low magnetic permeability stainless steel welds for microtron

Vacuum chambers of particle accelerators placed in the vicinity of magnets should have very low magnetic permeability so that the magnetic field in the magnet is not distorted. Stainless steel has been a material of choice for construction of vacuum chambers because of its excellent vacuum compatibility, manufacturability, mechanical properties and very low electrical conductivity. The only problem with this material is the difficulty in keeping the relative magnetic permeability close to unity after forming, machining and welding. Major sources of residual magnetic permeability in austenitic SS are formation of ferro-magnetic strain-induced martensite during machining and forming and ferro-magnetic -ferrite in the weld metal (WM). Welding filler wires for austenitic SS are usually designed to yield a duplex (austenite + δ-ferrite) WM to control solidification cracking.

The present Injector Microtron has served for 20 years and a project is currently underway to replace it with a new upgraded injector. Vacuum chamber of the existing Injector Microtron, made of AISI 304L SS and gas tungsten arc welded with ER 308L SS filler, has been found to be associated with asymmetric distribution of magnetic field across its diameter (Fig. A.16.1). It is reported that vacuum chambers and antechambers of Shanghai Synchrotron Radiation Facility were subjected to post weld heat treatment in a large vacuum furnace to bring down magnetic permeability of WM from 2.5 to 1.02. The unavailability of a large furnace to accommodate the manufactured vacuum chambers for solution annealing and the distortions arising in this process demand that the vacuum chambers retain their low magnetic permeability after the manufacturing processes so that the solution annealing is completely avoided. Based on the research work carried out to review role of δ-ferrite in suppressing solidification cracking, it has been suggested that higher Mn content in the WM is an effective way to obtain completely austenitic sound welds.

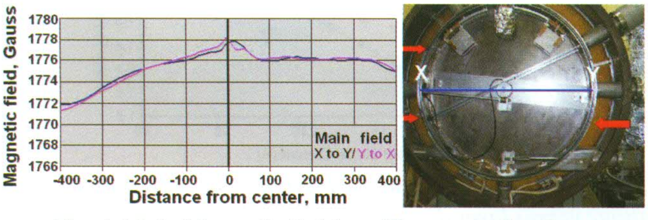

Fig.A.16.1: Magnetic field profile across the diameter of the vacuum chamber (XY) of Injector Microtron.

The experimental study performed on 40 mm thick plate of AISI 316 LN SS, was aimed to evaluate high Mn filler for obtaining crack-free non-magnetic austenitic SS weldments by GTAW. The filler selected for the study was a high Mn version of W 18 16 5 N L of ISO 14343 – 2009. Chemical composition (in wt. %) of the filler wire was: C ≤ 0.01; Cr: 18.7; Ni: 17; Mn: 5.1; Si: 0.4; Mo: 4; N: 0.15; S and P ≤0.01.

As welded SS plate was subjected to dye-penetrant, ultrasonic and radiographic examination and was found to be acceptable as per the provisions of section IX and section V of ASME Boiler & Pressure Vessel code.

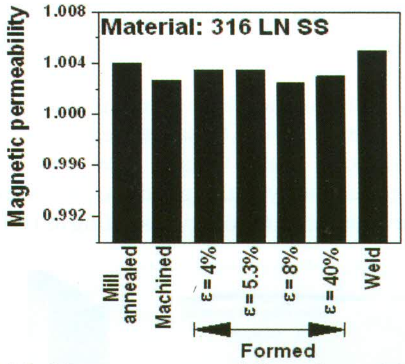

Fig.A.16.2: Magnetic permeability of type 316L and 316 LN stainless steels in different conditions

Magnetic permeability measurements, performed on 316LN plate in various fabrication conditions (viz. mill-annealed, machined, deformed and welded), demonstrated very little change in its magnetic permeability (Fig. A.16.2).The WM exhibited zero ferrite number (FN), indicating completely austenitic non-magnetic WM. Mechanical properties of the SS weld were: yield stress = 406 MPa; tensile strength = 613 MPa, elongation = 34% (50 mm gauge length). Guided bend tests, conducted in longitudinal face and root bend, transverse face bend and side bend configurations demonstrated soundness and ductility of GTA welds made with high Mn filler (Fig. A.16.3).

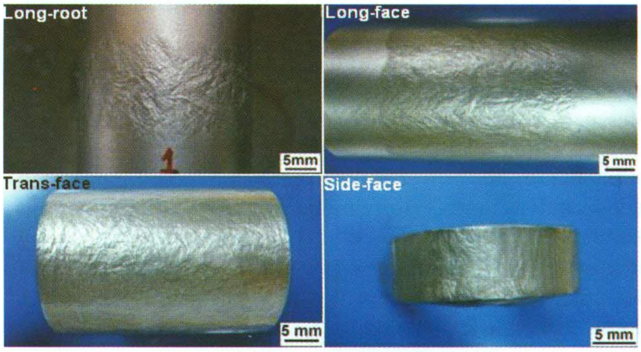

Fig. A.16.3: Photo-macrographs of convex surface of (A) longitudinal root bend, (B) longitudinal face bend, (C) transverse face bend and (D) side bend tested welded specimens.

The results of the study have demonstrated that AISI 316LN SS is a suitable choice as the material of construction of vacuum chamber. This material when welded with high Mn filler produced crack-free non-magnetic welds with acceptable mechanical properties.

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