A.14: Development of low magnetic permeability GTA welds of type 316L stainless steel for application in particle accelerators

Type 316L stainless steel (SS) is a strong candidate for being the material of construction of vacuum chambers of particle accelerators and helium vessel of superconducting radio frequency (SRF) cavities. Relatively higher magnetic permeability of its welds is one of the major impediments for its applications in particle accelerators.

In this regard, 316L SS welds with relative magnetic permeability (μ_r) close to that of the base metal were produced through addition of 1.5% nitrogen in the argon shield gas during gas tungsten arc welding (GTAW) with conventional ER316L filler metal. The resultant welds exhibited relative magnetic permeability close to that of the base metal at room temperature (RT) as well as at liquid helium temperature (LHeT), while recording an increase in nitrogen content from about 0.04 wt% to 0.15-0.2 wt%. Figure A.14.1 compares μ_r of 12 mm thick 316L SS GTA welds made with pre-mixed shield gas (Ar + 1.5% N_2) with those of base metal and welds made with argon shield gas.

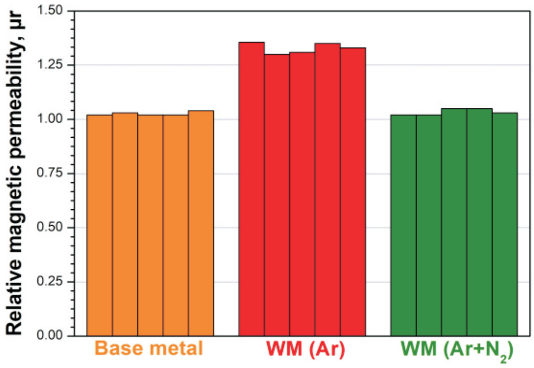

Fig. A.14.1: Comparison of relative magnetic permeability of base metal with welds made with Ar and Ar+1.5% N_2 shield gases.

The welded specimens (shield gas: Ar+1.5% N_2) exhibited RT tensile strength of 552 - 572 MPa, which is close to that of the base metal. The welded specimens, in face and root bend configurations, successfully passed guided bend ductility tests indicating ductile nature of weld metal (Figure A.14.2). The welded specimens also qualified Charpy impact test requirement of ASME Boiler and Pressure Vessel (B&PV) Code Section VIII Div-1 for operation at RT as well as at LHeT. Table A.14.1 summarizes impact energies of Charpy V-notch specimens of base metal and welds, tested at RT and liquid nitrogen temperature (LN_2T). Figure A.14.3 presents lateral expansion (LE) values of Charpy impact tested base metal and welded specimens, against the minimum LE value, specified by ASME

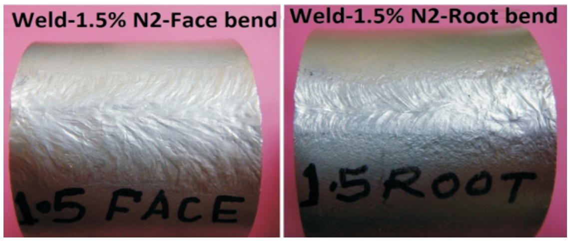

Fig. A.14.2: Guided bend tested GTA welded (shield gas: Ar + 1.5% N_2) 316L SS specimens.

B&PV Code. It should be noted that Section VIII, Division 1 of ASME B&PV Code permits the minimum design metal temperature to be lower than LN_2T if the weld is qualified at LN_2T against impact testing.

Table A.14.1: Impact energy of Charpy impact tested specimens of 316L SS

Test temperature	Base Metal	Weld (shield gas: Ar + N_2)
RT	254 - 296 J	276 - 296 J
LN_2T	212 - 248 J	114 – 154 J

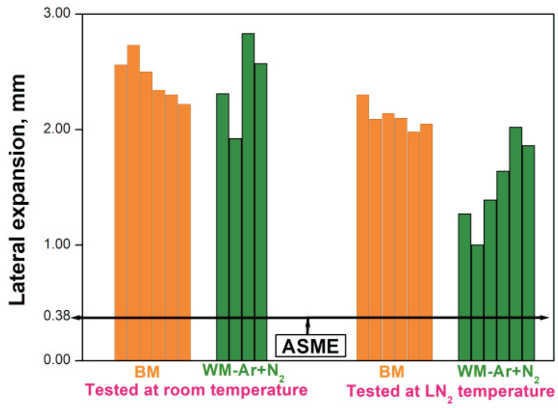

Fig. A.14.3: Comparison of lateral expansion (LE) values obtained from the Charpy impact tested specimens of base-metal (BM) & weld metal (WM) (Ar+1.5%N_2).

The newly developed technique is useful for fabrication of ASME B&PV Code Section VIII Div-1 compliant type 316L SS vacuum chambers and pressure vessels of particle accelerators for RT and LHeT applications.

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