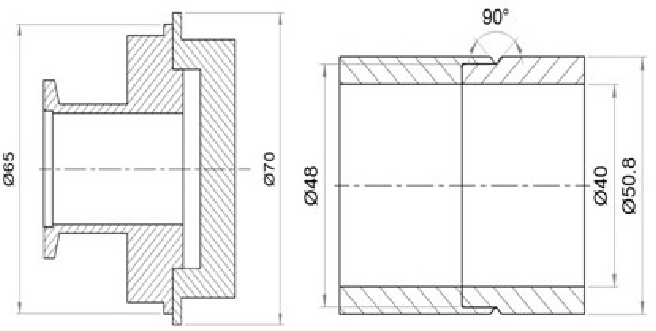
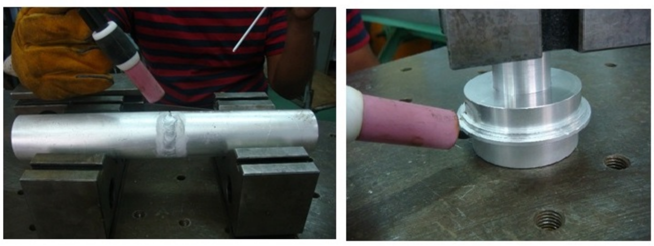
A.10: Investigation of UHV compatible weld joints of AA6061 for vacuum chamber of synchrotron radiation source

Aluminium alloys are used as construction material for ultra-high vacuum (UHV) chambers of synchrotron radiation sources (SRS) due to UHV compatibility, high thermal conductivity and non-magnetic requirements. In order to use indigenously developed diamond shaped metal gaskets (AA6063), AA6061-T6 base material with ER4047 filler alloy was explored as material of construction for upcoming dipole vacuum chambers. In this study, two low heat input weld designs, namely lip-fillet and lap-butt as shown in Figure A.10.1 were investigated for AA6061-T6, using gas tungsten arc welding (GTAW) process with filler alloy of ER4047, for assessing their compatibility for the UHV compatible leak tight application. Lip-fillet and lap-butt configurations are suitable for longitudinal and circumferential weld joints of a vacuum chamber from manufacturing and alignment point of views. GTA welded joints were characterized for leak tightness using helium leak test, thermal cycling and microstructural analysis using an optical microscope. Computational studies were carried out to analyse temperature distribution and resultant residual stresses in the welded test specimen with Simufact welding software using 3-D finite element analysis (FEA). Weld test specimen are shown in Figure A.10.2.



(a) (b)

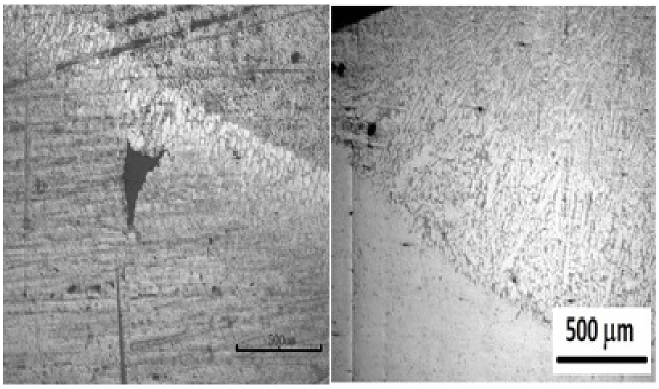
Fig. A.10.1: 2-D drawing of (a) lip-fillet, and (b) lap-butt weld design.



(a) (b)

Fig. A.10.2: Photographs depicting the GTA welds of specimens in (a) lap-butt and (b) lip-fillet configurations.

Helium leak tightness of 4.5×10^{-11} mbar.l.s^{-1} and 8.4×10^{-11} mbar.l.s^{-1} were obtained in lip-fillet and lap-butt welded test specimens, respectively which satisfies UHV requirement. Metallographic examination, as shown in Figure A.10.3 for lip-fillet (a) and lap-butt (b), showed that no cracks were emanating from root of the weld though there were region of lack of fusion at few location, which can be taken care of by adopting correct welding procedures.



(a) (b)

Fig. A.10.3: Microstructure of welded test specimen of AA6061 with ER4047 in (a) lip-fillet (b) lap-butt.

From FEA of welded test specimen subjected to moving heat source in the form of Goldak's double ellipsoidal model, maximum effective residual stresses of 125 MPa and 176 MPa were obtained in lip-fillet and lap-butt respectively, which were within design limits.

The welds of AA6061 with filler alloy ER4047 in the lip-fillet and lap-butt configurations qualified with respect to vacuum leak test with leak tightness better than 2×10^{-10} mbar.l.s^{-1}, which is suitable for UHV applications. The joint integrity is maintained even after exposure to 8 baking cycles at 150 °C for two hours each (assuming 6 to 8 times baking is carried out during the lifetime of the vacuum chamber). There are regions of lack of fusion at the weld root in some of the welds, however no sharp cracks were seen emanating from the root of weld. Apart from required leak tightness of the fabricated components, it should be ensured that full penetration is achieved consistently throughout the weld by appropriate non-destructive testing (NDT) before the components are put into service. Therefore, it has been proposed in the longitudinal direction for upgraded vacuum chambers of Indus-2 storage ring, lip-fillet weld design will be used as its manufacturing, machining and welding is easier, whereas for welding in circumferential direction, lap-butt configuration is proposed. This design can be further extended for future SRS vacuum chambers.

Reported by:
Sushil Kumar Sharma (sushilks@rrcat.gov.in)