ABSTRACT

Similar metal joining of commercially pure (CP) titanium and stainless steel AISI 304 were performed by laser beam welding (LBW) and electron beam welding (EBW), followed by laser shock peening (LSP). LBW was done at different welding speeds, and its influence on molten pool thermal history, microstructure, residual stress, mechanical and corrosion properties were studied. LSP of the welded specimens induced significant compressive residual stresses at the surface through plastic deformation and led to the improvement in microhardness (6-14% for SS and 7-26% for Ti) at the sub-surface region due to finer grain structure. Further, appreciable enhancement in tensile strength (13-29%) and fatigue life due to strain hardening and changes in microstructure like twinning within grains was realized. The properties of the EBW specimens were also improved by LSP. In the dissimilar metals welding process, longitudinal cracks and fractures occurred at low welding speeds due to the formation of hard and brittle intermetallics. Longitudinal cracks were mitigated at high welding speeds where the molten pool lifetime was less than 80 ms. Low molten pool lifetime prevented the growth of brittle intermetallics beyond a certain threshold. Transverse cracks across the joint due to the large difference in thermal properties of titanium and stainless steel were little influenced by the welding parameters. The transverse cracks could be reduced by shifting the laser beam towards Ti during welding. Employing a novel method of differential cooling during welding the thermal residual stresses were reduced and thereby transverse cracks were minimized by about 75%. Another novel method for in-situ deposition of powder of a compatible metal, Ni at their interface during laser welding, was developed. The interlayer mitigated the longitudinal cracks by acting as a barrier to elemental diffusion, thus restricting the growth of hard and brittle intermetallics of Ti and Fe. This also acted as a functionally graded layer to reduce the thermal residual stresses, thus preventing the formation of transverse cracks. An ultimate tensile strength as high as 375 MPa was obtained. This method has the flexibility to weld following three-dimensional contours and also to weld any other dissimilar metal combination by using an interlayer of a compatible material.

Keywords: Laser beam welding; electron beam welding, laser shock peening; stainless steel; titanium; dissimilar laser welding; intermetallics; differential cooling; directed energy deposition.