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Comparison of Microstructure, Mechanical Properties and Residual Stresses in Laser and Electron Beam Welded Ti–5Al–2.5Sn Titanium Alloy

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Abstract : Titanium alloys are widely employed in aerospace, medical, chemical, and marine applications. These alloys offer many advantages such as low specific weight, high strength to weight ratio, excellent corrosion resistance, high melting point and good fatigue behavior. These attractive properties make titanium alloys very unique and therefore they require special attention in all areas of processing, especially welding. In this work, 1.6 mm thick sheets of Ti-5Al-2,5Sn, an alpha titanium (α-Ti) alloy, were welded using electron beam (EBW) and laser beam (LBW) welding processes to achieve a full penetration Bead-on Plate (BoP) configuration. The weldments were studied using polarized optical microscope, SEM, EDS and XRD. Microhardness distribution across the weld zone and smooth and notch tensile strengths of the weldments were also recorded. Residual stresses using Hole-drill Strain Measurement (HDSM) method and deformation patterns of the weldments were measured for the purpose of comparison of the two welding processes. Fusion zone widths of both EBW and LBW weldments were found to be approximately equivalent owing to fairly similar high power densities of both the processes. Relatively less oxide content and consequently high joint quality were achieved in EBW weldment as compared to LBW due to vacuum environment and absence of any shielding gas. However, an increase in heat-affected zone width and partial ά-martensitic transformation infusion zone of EBW weldment were observed because of lesser cooling rates associated with EBW as compared with LBW. The microstructure infusion zone of EBW weldment comprised both acicular α and ά martensite within the prior β grains whereas complete ά martensitic transformation was observed within the fusion zone of LBW weldment. Hardness of the fusion zone in EBW weldment was found to be lower than the fusion zone of LBW weldment due to the observed microstructural differences. Notch tensile specimen of LBW exhibited higher load capacity, ductility, and absorbed energy as compared with EBW specimen due to the presence of high strength ά martensitic phase. It was observed that the sheet deformation and deformation angle in EBW weldment were more than LBW weldment due to relatively more heat retention in EBW which led to more thermal strains and hence higher deformations and deformation angle. The lowest residual stresses were found in LBW weldments which were tensile in nature. This was owing to high power density and higher cooling rates associated with LBW process. EBW weldment exhibited highest compressive residual stresses due to which the service life of EBW weldment is expected to improve.

Keywords : Laser and electron beam welding, Microstructure and mechanical properties, Residual stress and distortions, Titanium alloys
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