

Abstract

The full form of Laser is 'Light Amplification by Stimulated Emission of Radiation'. The most attractive and important properties of laser beam which are significant in material processing are high power, low divergence, directional, coherent and monochromatic beam. One of the most important characteristics of laser beam is its high energy density due to which it is widely used in welding of materials having high melting point. Titanium and its alloys serve as a bridge between the ideal properties of aluminum and steel. It is recognized as a workhorse for aerospace and automotive industries and is widely used in many areas such as aerospace, medicinal, chemical and aviation industries etc. due to its excellent combination of both high strength and ductility, low density, better corrosion resistance and excellent biocompatibility. The main goal of ongoing research work is to investigate the weldability of similar materials of Ti-6Al-4V alloy having thicknesses of 5, 2 and 1.5 mm and austenitic stainless steel of grade 316L (SS-316L) having thickness of 3 mm using fiber laser autogenously.

In the present study, a 2 kW solid state ytterbium doped fiber laser having wavelength of 1.08 μm combined with a computer numerical control worktable is used for welding experiments. A specially designed workpiece fixture with shielding gas delivery system is fabricated to reduce distortion and displacement of workpieces and to protect bead contamination from environment during welding. Three main process parameters which are considered are beam power, welding speed and defocused position of laser beam. The effect of process parameters on weld bead features like fusion zone width and area, size of heat affected zone at different locations in weld bead, bead shape, bead microstructure, weld defects and mechanical properties of the weldments are studied. The quality of the weldments is investigated via bead appearance under optical microscope, energy dispersive X-ray spectroscopy analysis, metallographic characterization of weld bead and testing of mechanical properties using Vickers microhardness tester and universal tensile testing machine. The weld bead microstructure is observed under optical microscope and their morphologies are compared using field emission scanning electron microscope. Further, the fractured surfaces are analyzed using FESEM images to confirm different modes of fracture failure i.e. ductile or brittle fracture. Further welding experiments are extended to optimize the process parameters using response surface methodology of statistical design of experiments for achieving satisfactory weld quality. Analysis of variance (ANOVA) is carried out to identify the most significant process parameters during welding for both Ti-

6Al-4V and SS-316L workpieces and their percentage contribution on output responses are calculated. After that regression analysis is carried out. The effect of individual process parameters and their combined effect are studied using 2D and 3D response plots obtained from regression equations. Further, a three-dimensional finite element based model is developed using ANSYS® 14.5 to determine transient temperature profile around weld pool.

Experimentally it is observed that penetration depth in the base plate is primarily controlled by beam power density on workpiece surface. However, width of fusion zone and size of heat affected zone depend on line energy. In the present study, almost linear relationship between width of FZ and line energy is observed irrespective of penetration depth in the base plate. Smooth, uniform, acceptable size of micro pores, shiny bead with no spatters and crack free weld bead is formed. Welding power shows positive effect on bead features whereas welding speed shows negative impact. However, defocused position of the laser beam shows diverse effect on bead geometry. The weld bead is almost symmetrical about the centre line of fusion zone. Moreover, lack of symmetry is only observed at higher beam power on root side of weld bead. Presence of α' martensitic phase having needle shaped structure in the fusion zone reflects high self-quenching characteristics of laser beam welding process. In the present study, most of the welded samples are defects free. Although, in few welded samples small amount of underfill defect, excess penetration and porosity are observed in the weld bead. However, the size of the porosities is within acceptable range (< 0.4 mm) as per BS EN: 4678:2011 European standard. Maximum hardness value is observed in the fusion zone for both Ti-6Al-4V and SS-316L and its value continuously decreases towards BMZ. The percentage elongation of the welded specimens is found lower than base metal due to the presence of brittle α' martensitic phase in the FZ which possess high tensile strength at the expense of ductility. Ductile mode of fracture failure is observed in both base metal as well as in welded specimen of Ti-6Al-4V and SS-316L. A FEM based numerical simulation of laser welding process is developed for transient thermal analysis of Ti-6Al-4V workpiece by employing double ellipsoidal and 3-D cone-shaped volumetric heat source models. A non-linear relationship between peak temperature and beam power is noticed possibly due to the variation of Ti-6Al-4V alloy's absorption coefficient with temperature. The present model can be useful to reduce the number of trial experiments before performing the actual experiment which helps in reducing experimental cost.