ABSTRACT

In the present research, commercially pure titanium (CP Ti) tailor welded blanks (TWBs) were fabricated using electron beam welding (EBW) with an accelerating voltage of 55 kV, beam current of 15 mA and welding speed of 865 mm/min. Additionally, CP Ti-Ti6Al4V TWBs were also manufactured using an accelerating voltage of 55 kV, beam current of 16.5 mA and welding speed of 850 mm/min. Forming behavior of these TWBs was investigated using uniaxial tensile tests, limiting dome height (LDH) tests, deep drawing tests and single point incremental forming (SPIF) tests. Two types of CP Ti TWBs were fabricated with weld line perpendicular (WL ⊥ RD) and parallel (WL || RD) to rolling direction (RD). In both these CP Ti TWBs, the microstructural analysis revealed that the fusion zone (FZ) exhibited coarsened prior β grains with internal α substructures, and the microhardness observations across the weld revealed that the hardness of the FZ was higher compared to that of the CP Ti parent materials. It was found that the weld line orientation with respect to RD significantly influenced the tensile response of the TWBs, and lower elongation and ultimate tensile strength were observed in the WL || RD configuration. The EBSD analysis revealed the activation of different slip and twin systems depending on the loading direction with respect to RD, and it led to variations in yield strength. In CP Ti-Ti6Al4V TWBs, the FZ consisted of needle-like α′ martensite with four axis/angle misorientation peaks, which were found to be associated with the formation of certain crystallographic variants of α phase during cooling. The microhardness of the FZ was higher than that of the CP Ti owing to the presence of α′ martensite and higher volume concentration of alloying elements viz. Al and V across the weld. These TWBs exhibited intermediate yield strength and ultimate tensile strength compared to those of the parent materials. The forming limit diagram (FLD) of the CP Ti TWBs was observed to be influenced by the weld line orientation, with lower LDH values in WL || RD under tension-tension conditions and higher LDH values in WL || RD under tension-compression conditions. The CP Ti-Ti6Al4V TWBs demonstrated higher FLD than Ti6Al4V parent material, attributed to the presence of ductile CP Ti in the TWB. In the deep drawing of CP Ti TWBs, the results showed that the LDR of the TWB was similar to that of the CP Ti parent materials. However, severe non-uniform material flow occurred in deep drawing of CP Ti-Ti6Al4V TWBs due to the significant strength and ductility disparity between the parent materials. The CPB06 yield criterion and weld properties were incorporated in an FE model to predict the deformation behavior of CP Ti TWBs in deep drawing and SPIF processes. The incorporation of the CPB06 yield criterion accurately predicted non-uniform material flow and thickness distribution, taking into account the strength differential and anisotropy properties.

Keywords: Commercially pure titanium, Ti6Al4V, Electron beam welding, Tailor welded blank, Microstructure, Forming limit diagram, Deep drawing, SPIF, Finite element model, CPB06 yield criterion