Abstract

The effect of thermo-mechanical treatments on the microstructural and microtextural evolution of Al-4.5wt.%Cu-5wt.%TiB_2 in-situ composite, prepared through mixed salt reaction route followed by stir casting, has been methodically examined, and the structure-property relationships have been investigated. The as-cast samples were subjected to hot rolling (370°C, 5% reduction), mushy state rolling (626°C, 5% reduction), and mushy state rolling with prior cold rolling (30% reduction) and are referred as HRC, MRC, and PCMRC, respectively. The HRC has shown a completely recrystallized fine-grained structure with a network of $CuAl_2$ and TiB_2 particles at the grain boundaries. On the contrary, both MRC and PCMRC have shown gradient microstructure containing deformed grains with a higher density of low angle boundaries at the center than that near the edge of the longitudinal-transverse plane. This finding strongly suggests the greater deformation of α-Al solid skeleton at the center due to the liquid oozing to the edges under the compressive action of the rolls during mushy state rolling. Particle stimulated recrystallization has been also confirmed for all set of rolled composites through electron back-scattered diffraction (EBSD) and transmission electron microscopy (TEM). Fragmentation and the redistribution of the reinforcement particles happening in course of rolling have been quantified using X-ray computed tomography and multi-scalar analysis of area fraction technique. Hardness, tensile and creep properties, as well as dry sliding wear behavior, have been evaluated for all types of composite samples and compared. The PCMRC has exhibited an excellent combination of mechanical properties like hardness, tensile strength (UTS: 301.4±1.8 MPa) and ductility (30.8% ± 0.5%), and creep resistance (lowest creep rate, $\acute{\varepsilon}_s \approx 1.39\times10^{-10} s^{-1}$ and highest time to rupture, t_r= 904 h), as well as wear resistance, which have been found superior to those of other composites. The maximum homogeneity of Cu content, as well as that of $CuAl_2$ and TiB_2 particle distribution, together with the formation of the high density of low angle boundaries in α-Al matrix, promoted by cold rolling treatment prior to the mushy state rolling, has contributed towards the superior properties observed in the PCMRC. Presence of occasional clusters of reinforcement particles in the MRC is considered as responsible for poor ductility. Inferior hardness and strength; yet a reasonable uniform elongation and strain hardening rate have been observed in the HRC, which is attributed to its recrystallized microstructure. The wear rate has been found to decrease with increasing homogeneity of $CuAl_2$ and TiB_2 particle distribution and pre-wear hardness. The wear mechanism has been found to involve adhesive interaction and micro-ploughing of the matrix by the asperities on the mating surface of the steel disc and de-bonded TiB_2 particles. The worn surfaces have exhibited the formation of a protective and lubricating mechanically mixed layer consisting of Fe_2O_3 and Al_2O_3, which lowers the wear rate. A detailed EBSD analysis of the post-wear subsurface region has been carried out to examine microtexture evolution due to work-hardening during sliding, as confirmed by measurement of hardness increment at post-wear subsurface locations. Creep curves have shown three distinct stages of creep at 275°C for all types of rolled composites, and only for the PCMRC at 300°C.The lowest steady-state creep rate and highest time to rupture at both 275°C and 300°C have been observed in the PCMRC owing to its highest low angle boundary density, finer $CuAl_2$ precipitates, and smaller inter-precipitate spacing. Damage during creep involves $CuAl_2$ precipitate coarsening, grain growth and cavity formation at particle-matrix interfaces.

Keywords: In-situ composite; Mushy state rolling; Microstructure; Microtexture; Hardness; Tensile strength; Dry sliding wear; Tensile creep.