Generation of Nano-sized Grains by High Pressure Torsion (HPT) and Evaluation of Microstructure and Mechanical Behavior in a ٢٠٢٤ Aluminium alloy

Abstract

In the present study, the process of high pressure torsion (HPT) is used on a commercial ٢٠٢٤ aluminium alloy in order to evaluate the effects of SPD on microstructure, flow stress and hardness at various conditions of temperature, aging and strain rate. The results indicated that not only a very fine microstructure is achievable by this process, but also aging behavior accompanied with SPD can produce special effects on final mechanical properties of this alloy. Studies on severely deformed samples by optical microscopy (OP), scanning electron microscopy (SEM), transmission electron microscopy (TEM), high resolution transmission electron microscopy (HRTEM) and selected area electron diffraction (SAED) have clearly indicated that structures down to nano-sized grains can be achieved by HPT processing technique. The influential effects of intermetallics and different precipitates already present in the alloy as well as aging constituents, precipitated before, during and after HPT processing on grain refinement and mechanical properties were also studied. The results indicated that alloying elements and temperature have marked influence on grain morphology and ultra fine grain refinement. Coarse intermetallics did not seem to have a noticeable effect on the mechanisms of grain refinement. Such compounds were simply fragmented and distributed or dissolved in the microstructure during SPD process. Energy dispersive spectroscopy (EDS) analysis of alloying elements provided the identification of soluble and insoluble compounds within the matrix. Furthermore, the insitu behavior of flow stress during HPT deformation and post-microhardness measurements on samples deformed at different temperatures (in the range of -١٩٦°C to ٤٠٠°C) clearly indicated that HPT processing technique is an effective means of acquiring very high hardness (three folds of original value) and flow stress in this alloy. The production of ultrafine nano-sized grains of ٢٠-٦٠ nm by this process at -١٩٦°C resulted in highest flow stress though no marked increase in hardness in comparison with HPT deformed samples at room temperature was observed. A marked difference between microhardness distribution across the diameters of pre aged and post aged samples were recorded which indicated the influential effects of aging constituents on the microstructure of the alloy. The best uniformity in distribution of microhardness was measured on HPT deformed samples, post-aged at ١٩٠°C. Also insitu HPT deformation at various strain rates in the range of ٠,٠٤-٠,٦ rev/min at different temperatures showed no noticeable effect on flow strength of the alloy.

Keywords: Aluminium alloy; High pressure torsion; Nano-sized structure; Electron microscopy;
Micro-hardne Aging