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Deformation Response of Mg-Y Alloys under Dynamic Loading

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Extended Abstract

Weight reduction of automobiles and aircrafts improves fuel economy and reduces greenhouse gas emissions. Use of Mg alloys may allow weight reduction because of their low densities, but adoption is hindered because they exhibit limited ductility at ambient temperatures [1]. In a previous study of fracture toughness in a Mg alloy, crack readily propagated near twin boundaries and resulted in poor durability [2]. It has been shown that pile-up of dislocations at the interface between the matrix and deformation twins caused stress concentration to form cracks [2]. Another study suggested that the ductility of Mg alloys is further limited under dynamic loading due to lowered activity of dislocations [3]. It has also been reported that a Mg-Al-Mn alloy had pronounced mechanical anisotropy at high strain rates of around 1.0×10^3 s^{-1} [4]. Therefore, the mechanical properties of Mg alloys should be evaluated accurately for applications involving possible dynamic loading.

It has been reported that addition of rare earth elements such as yttrium may improve mechanical properties over conventional Mg-Al-Zn alloys by minimizing intensity of the basal texture [5–9]. However, the deformation behavior of Mg alloys containing yttrium is not sufficiently understood at strain rates exceeding 1×10^3 s^{-1}. This study examines a binary Mg-Y alloy at high strain rates in compression to clarify the effect of yttrium addition on the mechanical properties. Details have been reported elsewhere [10].

This study investigated a binary Mg-0.6at.%Y alloy. A billet was fabricated by gravity casting into a steel mold. The cast binary alloy was homogenized at 773 K, followed by quenching in water. It was then extruded at 673 K at a ratio of 25:1. The extruded rod having a diameter of 8 mm was annealed at 673 K for 16.5 h to form an equiaxed grain structure with an average grain size of 42 μm. As a reference material, extruded magnesium with 99.95% purity and an average grain size of 50 μm was prepared. Cylindrical specimens having a height of 8 mm and a diameter of 4 mm were machined parallel to the extrusion direction. To examine the mechanical anisotropy, cylindrical specimens of height 6.5 mm and diameter 4 mm were also prepared along two directions, parallel and perpendicular to the extrusion direction. High strain rate compression tests were performed by using a split Hopkinson pressure bar (SHPB) at ambient temperature (298 K). The average strain rate was measured to be 1.4×10^3 s^{-1} for a specimen of 8.0 mm height and to be 1.7×10^3 s^{-1} for a specimen of 6.5 mm height. The shape of the specimen during deformation was detected as a series of images by an ultra-high speed camera (Shimadzu HPV-1) with a sampling time of 4 μs.

By investigation of the Mg-0.6 at.% Y alloy and comparing it with a commercial purity magnesium sample, we have found that yttrium solute contributed to enhanced compressive ductility, reduced strain hardening rate, and minimized deformation asymmetry in magnesium, even under dynamic loading. Although $\{10\bar{1}2\}$ twins were the predominant deformation mechanism for the Mg-0.6Y alloy in the early-stage of deformation, cracks did not initiate near these twin boundaries, unlike in the conventional Mg alloy AZ31. This suggests occurrence of stress relaxation during deformation. Subgrain formation and c-axis rotation possibly release stress concentrations during high strain rate deformation of the Mg-Y alloy.

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