論文の内容の要旨

論文題目

Evaluation of Deformation and Pseudoelastic Behavior of Pure magnesium and its Alloys by AE

(AEによるMg及びMg合金の変形と擬弾性挙動の評価)

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Present study provides in materials science and engineering a new way of investigating the deformation and pseudoelastic behaviors of not only the magnesium and its alloys but also other materials with similar mechanical properties such as Ti alloys or shape memory alloys by quantitative method of AE technique.

The deformation and the anelastic recovery behavior of pure magnesium and its alloys were conducted by acoustic emission. Due to the HCP crystalline structure, the deformation of magnesium and its alloy shows a distinct behavior compared to the other materials of such as FCC or BCC structure, because twinning plays an important role in the deformation process. During the cyclic deformation process, broad hysteresis loops can be observed for magnesium and its alloys. Such psuedoelasticity of magnesium and its alloys are thought to be due to the twinning detwinning process during the loading and unloading process, respectively. The twins in the deformed state are not stable, and a driving force may cause them to disappear or shrink by movements of the boundaries upon unloading. The twinning and detwinning are both very important sources of AE because there are strong elastic waves released during these processes.

The deformation process was mainly conducted in the relationship between the twinning process and AE signals. By analyzing the AE activities of pure magnesium specimen with an average grain size of about 35μm in different environments, it was found that the AE signals emitted in the deformation process of pure magnesium are mainly from the twinning activities in the initial stage of deformation. In the later stage, increasing strain leads to the nucleation of only a few mechanical twins since the dislocation movement becomes more dominant with a result of decrease of the AE number. The twinning length distribution of pure magnesium with an average grain size of about 35μm reveals the twinning behavior that the deformation was mainly accommodated by the twinning nucleation before the true strain of about 0.7% and by the twinning growth at higher strain levels. Twinning strain was calculated by considering the variation of Schmid factor in the deformation process of the basal plane textured structure and the results showed that there is an exponential relation between twinning strain and the corresponding cumulative AE counts in the initial stage of compression process by $N^{1/P}=k\varepsilon_{tw}$. This relation approximately demonstrates the relation between the cumulative AE counts and twinning strain accommodated by twinning nucleation. The calculated twinning strain and the corresponding cumulative AE counts in deformation process for pure magnesium with different grain size and strain rate also have the same relation with a variation of the parameter k according to the experimental condition, while the parameter P was found to have nearly the same value of about 1.26 for variant samples. For magnesium alloys, relatively weak AE signals were observed In AZ61 and ZW3 alloy compared to the AE31B alloy and pure magnesium, due to the finer grain size in AZ61 and ZW3 alloys. Due to the PLC effect, the AE spikes were observed in the relative high strain level (>2%), although the entire AE signals became weaker with the increase of strain level. The basal plane textured pure magnesium, when compressed parallel and vertical to the extrusion direction, exhibited different defomation behaviors. By analyzing the twinning density and the characteristics of AE signals, it was found that the defomation behavior is closely related to twinning behavior in different loading directions.

The AE behavior of anelastic recovery process was measured in pure magnesium and the linear relationship between parameters $N^{1/3}$ and ε_r was observed. A model for the detwinning process of pure magnesium and its alloys as a function of applied strain was proposed, and showed a good agreement with the experimental results in both pure magnesium and its alloys.

Three anelastic recovery stages were observed in pure magnesium in the samples with four different grain sizes: the detwinning of {10-12} system, dislocation dominated recovery process as well as other detwinning system. It was found that the grain size has a great effect to the fraction of anelastic recovery strain by detwinning, and the slope of the linear relation k between anelastic recovery strain and cubic root of cumulative AE counts was found to be followed by the near Hall-petch relation of $k=k_0-Dd^{-1/2}$, and the faction of anelastic recovery strain by detwinning and dislocation motions were separated successfully for the first time by this equation.

It was supposed that the twinning in the vertical sample was more unstable and easier to detwin than that of the parallel sample, because the twinning is difficult to form in the vertical sample and the formed twins are prone to detwin in appropriate conditions.

The shrinking of the size of hysteresis loops, stress decrease, as well as the decrease of the cumulative AE counts and anelastic recovery strain were observed in the strain controlled cyclic process. The strain fraction of detwinning in anelastic recovery process was found to be increased with the increase of cyclic number, although the absolute value of the anelastic recovery strain by detwinning was observed to decrease greatly in the strain controlled cyclic process. The true strain dependence of fractions of anelastic recovery strain by detwinning for three samples with different strain rates have similar trends: in the initial stage of deformation, the highest fraction value was observed, and later, the value decreases greatly. However, the average fraction of anelastic recovery strain by detwinning for the sample with high strain rate has the highest value.