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6th New Methods of Damage and Failure Analysis of Structural Parts [MDFA]

Cyclic Bending Deformation and Fracture of Al and Al-1.0mass%Mg Alloy

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Abstract

The characteristics of cyclic bending deformation and fatigue fracture are studied on polycrystalline aluminum and Al-1.0mass%Mg alloy from the metallurgical point of view. It is found that the fatigue life mainly depends on grain size and the kind of materials. Cracks are preferentially formed at grain boundaries inclined 40 – 60° to the tension-compression direction, suggesting that shear stress affects the crack formation. EBSD measurements reveal the inhomogeneity of deformation. Intense development of sub-grain is seen in the grain interior close to a crack. It indicates that the work hardening close to grain boundaries triggers the crack formation.

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Materials Engineering

Keywords: bending fatigue, grain size, crack generation, work hardening

1. Introduction

Weight reduction is one of the important issues in automobile industries today, because it contributes to the improvement in fuel efficiency of vehicle and thus leads the CO_2 reduction. Weight saving has been challenged on all kinds of automotive components. Of course the electrical cables which account for about 60% of wire harnesses are also an objective for the weight reduction. Since the electrical conductor is the heaviest element in the electrical

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cables, replacing of the conventional electrical conductor with lightweight materials is quite effective for reduction in weights. Copper has been employed as electrical conductors in conventional electrical cables, while aluminum alloys have been extensively studied as an alternative for copper for its lightness in weight, good strength and high electrical conductivity. The replacement of electric wires made of copper with aluminum alloys gives the solution for the exhaustion of copper resources at the same time.

Application of aluminum based alloy conductors to electrical cables is, however, quite limited at present, due to inadequate combinations of strength, electrical conductivity and fatigue resistance in comparison with copper. In order to expand the application field of aluminum conductor, it is essential to develop aluminum based materials with enough strength and fatigue resistance without degrading electrical conductivity.

Although many studies have been conducted on the fatigue of copper and aluminum [Lei Zeng et al., (2012) for example], there is dearth of information on cyclic bending fatigue at the conditions close to in-vehicle application. The fatigue process at the cyclic bending is also not yet clarified enough.

In the present study, cyclic bending fatigue behaviors of pure aluminum and Al-Mg alloy were investigated in the condition close to in-vehicle application. As it is already reported that grain size as well as crystal orientation distribution gives effects on the deformation behavior of polycrystalline materials [N. Kamp et al., (2007)], special attention is paid on the effect of grain size on the fatigue bending life.

Nomenclature

ε	maximum bending strain
d	thickness of specimen
R	bending radius
N_f	number of cycles to failure
GB	grain boundary
KAM	kernel average misorientation

2. Experimental

2.1. Material

The test materials are 99.99% aluminum and Al-1.0mass%Mg alloy in a polycrystalline state. As a reference, pure copper was also investigated. Al-Mg alloy was produced by melting 99.99mass% pure aluminum and 99.9mass% pure magnesium in a high-frequency induction furnace. The billet with a diameter of 25 mm was obtained by casting method. Then, the diameter of the billet was reduced to 4.9 mm by cold rolling and drawing. The billets of pure aluminum and aluminum alloy were annealed at 673 K for 3.6 ks in an air. The billet of pure copper was annealed at 873 K for 3.6 ks in nitrogen atmosphere. Then, further drawing to a diameter of 1.0 mm was conducted. After the drawing, the materials were annealed at the same conditions as the first heat treatment. Finally, the wire rod was processed into a shape shown in Fig. 1 by a drawing process. After the final drawing, the specimens were heat-treated at various temperatures to control the grain size. Table 1 shows the grain sizes of the three materials.

Table 1. The grain size of specimens.

Material	Grain size (μm)			
Aluminum	80	150	190	300
Al-1.0mass%Mg	60	100	150	210
Copper	30	50	70	90

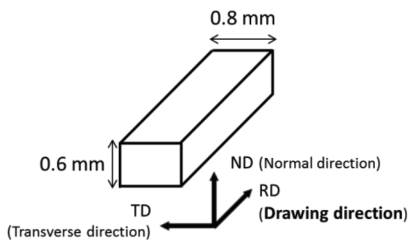

Fig. 1. Dimension of the wire after the final drawing.