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HYDROGEN INTRODUCTION TO 6061 ALUMINUM ALLOY BY FRICTION IN WATER AND ITS EFFECTS ON MECHANICAL PROPERTIES

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INTRODUCTION

6061-T6 aluminum alloy is recognized as an alloy for liner materials used for a high pressure hydrogen gas tank in a fuel cell vehicle. It is known that this alloy has low susceptibility to hydrogen embrittlement under high pressure hydrogen environment, however, the reason for this low susceptibility is not sufficiently understood (Osaki et al., 2006). In the present study, we introduced hydrogen into 6061 aluminum alloys containing different amount of iron by means of friction in water, and examined the mechanical properties.

EXPERIMENTAL

The 6061 aluminum alloys containing different amount of iron were prepared. The chemical composition of the alloys is shown in Table 1 (refer to as 0.1%Fe, 0.2%Fe, 0.7%Fe). These alloys are subjected to solution treatment at 530°C for 30 min, water-cooled, artificial aging at 160°C for 18 h (T-6 treatment). The tensile specimen was prepared such that the length of the parallel part was 10 mm, the width of parallel part was 5 mm, the radius of the shoulder part was 1 mm, and the longitudinal direction was parallel to the rolled direction. In addition, the surface of the specimen was polished by using emery papers (#800, 1200) and buffed by alumina (particle diameter 0.3 µm). In this study, hydrogen was charged into the alloys by friction in water. The apparatus is designed to enable hydrogen introduction into the specimen by continuous friction in water. Waterproof abrasive paper (#2000) was attached to the bottom of a glass vessel and 100 ml pure water was added. The glass vessel was fixed on a magnetic stirrer. The specimen was adhered at the bottom of the triangular prismatic stirring bar, and the stirrer was rotated at 60 rpm for 1 h on the abrasive paper in the vessel. The specimen subjected to friction in water is referred to as Fri., and the specimen without friction in water is referred to as non_Fri.. In order to examine the amount of hydrogen introduced into the specimen by friction in water, each sample was subjected to thermal desorption hydrogen analysis (TDA: 100°C/h, room temperature~625°C). The tensile property and the hydrogen evolution behavior were examined by using a tensile testing machine equipped with a quadrupole mass spectrometer installed in an ultra-high vacuum chamber.

Table 1. Chemical composition of 6061 aluminum alloys (mass %)

Alloy	Mg	Si	Fe	Cu	Cr	Al	grain size (µm)
0.1%Fe	1.0	0.82	0.08	0.42	0.19	Bal.	57.8
0.2%Fe	1.0	0.79	0.20	0.42	0.19	Bal	39.0
0.7%Fe	1.0	0.81	0.68	0.43	0.20	Bal.	23.3

RESULTS

The result of TDA in each alloy is shown in Figure 1. The amount of hydrogen introduction increased by friction in water. For the alloys subjected to friction in water, a single peak of hydrogen evolution was observed around 500°C, and the magnitude of the peak increased with the increase of iron content. Therefore, the peak of hydrogen evolution observed around 500°C would be related to hydrogen trapping by iron base intermetallic compounds. Considering previous reports (Minoda et al., 2003; Toda et al., 2001), the intermetallic compounds observed in the present study are considered to be AlFeSi phases.

The result of tensile test in each alloys is shown in Figure 2. The ductility of 6061 aluminum alloy containing 0.1 mass % Fe decreased by friction in water, while the ductility of the alloys containing higher amount of iron (0.2%Fe, 0.7%Fe) did not decrease even after friction in water. Hydrogen release in the plastic deformation was observed more prominently in the alloys containing higher amounts of iron (0.2%Fe, 0.7%Fe). High amounts of hydrogen were also evolved when all of the alloys were fractured.

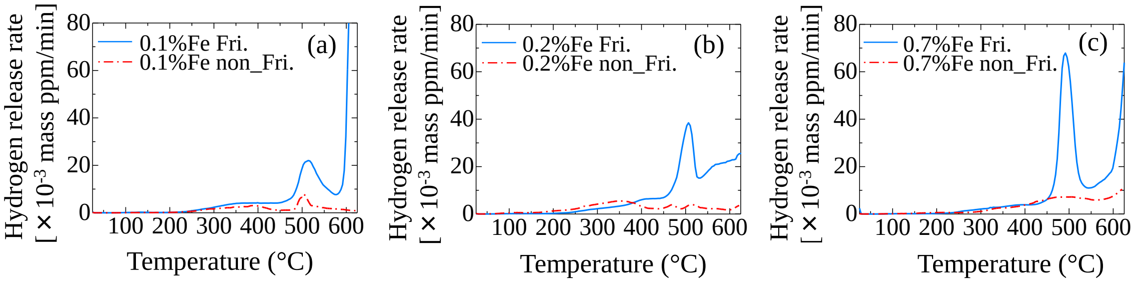

Figure 1. Hydrogen thermal desorption analysis for (a) 0.1%Fe, (b) 0.2%Fe, and (c) 0.7%Fe

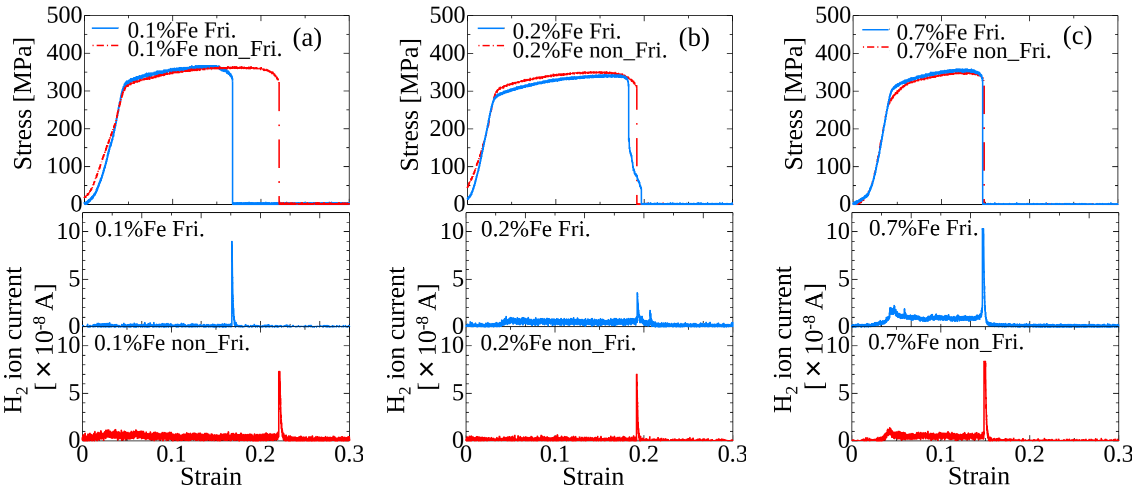

Figure 2. Stress-strain curves and hydrogen evolution behavior in (a) 0.1%Fe, (b) 0.2%Fe, and (c) 0.7%Fe. The upward arrows indicate that the content of released hydrogen at the time of rupture was overscaled

CONCLUSIONS

Hydrogen was successfully introduced into 6061 aluminum alloys by polishing the surface continuously in water. The ductility of 6061 aluminum alloy containing 0.1 mass % Fe decreased when the surface was preliminarily polished in water. On the other hand, the ductility of the alloys containing higher amount of iron (0.2%Fe, 0.7%Fe) did not decrease even after polishing the surface in water.

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KEYWORDS

Al-Mg-Si alloy, Hydrogen, Tensile property, Impurity effect