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Fatigue and hydrogen embrittlement properties of Al-Mg-Zn series casting alloy with Cu addition.

Yudai Nasu[1], Tadao Fukuta[2] , Kiyotaka Obunai[2] and Koichi Ozaki[2]
[1] Graduate School of Okayama Prefectural University Department of Systems Engineering
[2] Okayama Prefectural University Department of Systems Engineering

The purpose of this study is to improve the fatigue and hydrogen embrittlement properties of Al-Mg-Zn series cast alloy by adding Cu. The weight fractions of Mg, Zn and Cu in the cast alloy were controlled to 3.6, 3.0 and 0.9 mass%, respectively. In order to obtain higher mechanical properties the aging heat treatment was conducted to casted alloy ingots. The fatigue strength of cast alloys was characterized under cyclic sinusoidal tensile load by using fatigue tester. The creep strength under corrosive environment of cast alloy was also measured to evaluate the hydrogen embrittlement characteristics. The surface of specimen dipped into NaOH solution was observed for measuring the amount of hydrogen generation by corrosion. Moreover, in order to discuss the effect of Cu addition on grain boundary strength, first principle calculation was conducted. Test results showed that the fatigue strength of proposed alloy was improved compared to that of conventional Al-Mg-Zn alloy. The creep strength of proposed alloy was also improved. Calculated results revealed that the grain boundary strength was improved when Cu was existed. These results revealed that the addition of Cu was effective to improve the fatigue characteristics of Al-Mg-Zn alloy by enhancing the grain boundary strength.

Keywords: *Fatigue property, Hydrogen embrittlement, Grain boundary strength, AC7A*

1. Introduction

Nowadays, aluminum casting wheel were often appeared in automotive to reduce the weight and inertia and also to put the grace for many user. Many of aluminum casting wheel were made from AC4CH and to obtain shiny surface, plating technique was required. From the viewpoint of environmentally friendly, Al-Mg-Zn series casting aluminum that can obtain shiny surface without plating have been developed by one of the authors[1]. However, the fatigue strength of Al-Mg-Zn series casting aluminum was considerably lower than that of AC4CH. In this study, in order to improve the fatigue strength of Al-Mg-Zn series casting aluminum, the Cu was used as new additive and its effect on fatigue strength was investigated. To applying the automotive wheel, various mechanical characteristics have to consider not only under lab environment but also under corrosive environment. Therefore, the creep strength of developed alloy was also investigated by controlled corrosive environment.

2. Experimental procedure

Table 1 show the chemical composition of alloys. The conventional Al-Mg-Zn alloy and developed alloy were casted to ingot. The solution heat treatment and age hardening treatment was conducted to casted alloy ingots. Table 2 shows the conditions for heat treatment of each test samples. The conditions for heat treatment were decided by investigating the strength and fracture strain of each treatment conditions. By using dumbbell type specimen, the tensile properties of cast alloys in which conditions for heat treatment were different were characterized under of 1.0 %/min of constant uniaxial strain. The fatigue strength of cast alloys was also characterized under cyclic sinusoidal tensile load by using hydraulic type fatigue tester. Stress ratio for fatigue test was set to 0.1. The creep strength under controlled corrosive environment of cast alloy was measured to evaluate the hydrogen embrittlement characteristics. In this study, the creep strength was defined as the applied stress when time until fracture reaches 240 hour. Constant tensile load was applied to small dumbbell type specimen with circumferential V notch by using lever type creep tester shown in Fig.1. The wet-dry cycle corrosive environment was simulated by dropping the NaOH solution to gauze wrapped around V notch. For measuring the amount of hydrogen generation under corrosive environment, coupon type specimen was also prepared. The tensile load was applied to polished specimen in NaOH solution, and its surface was observed.

Tabel 1 Chemical composition (mass%).

	Mg	Zn	Cu	Si	Al
AC7A+CuZn	3.6	3.0	0.9	-	Bal
AC7A+Zn	4.5	3.1	-	-	Bal
AC4CH	0.25-0.45	-	-	6.5-7.5	Bal

Tabel 2 Heat treatment conditions.

	Solution treatment	Age hardening treatment
AC7A+CuZn	753 K-6h	453 K-5h
AC7A+Zn	703 K-6h	453 K-5h
AC4CH	808 K-4h	433 K-4h

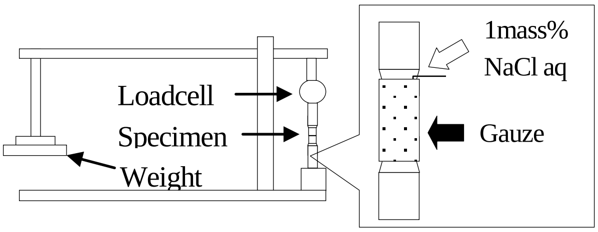

Fig. 1 Schematic diagram of apparatus.

3. Results and discussion

Tensile test results revealed that when applying the appropriate heat treatment, the tensile strength and fracture strain of developed alloy was almost same as that of conventional Al-Mg-Zn alloy. Figure 2 shows the S-N diagram of test samples. Test results showed that the fatigue limit of developed alloy was improved by adding the Cu and removing the Mg from conventional alloy. In order to reveal the morphology of Cu in alloy, FE-EPMA analysis was conducted. The FE-EPMA analysis of proposed alloy revealed that the added Cu was segregated to the grain boundary. One of the authors reported that the grain boundary cohesive energy evaluated by first principle calculation was improved when segregated Cu was existed at modeled grain boundary of Al-Mg-Zn series alloy[2]. These results suggested that the improvement in fatigue strength of developed alloy was explained by the improvement in grain boundary strength. Figure 3 also shows the results of the creep test under corrosive environment. The creep strength of developed alloy was improved compared with that of conventional alloy. The surface observation of specimen in corrosive environment revealed that when load was applied, the generated hydrogen by corrosion was absorbed into the specimen. The amount of hydrogen absorption of developed alloy was almost same as that of conventional alloy. These results suggested that the addition of Cu was effective to enhance the grain boundary strength even if the hydrogen was absorbed.

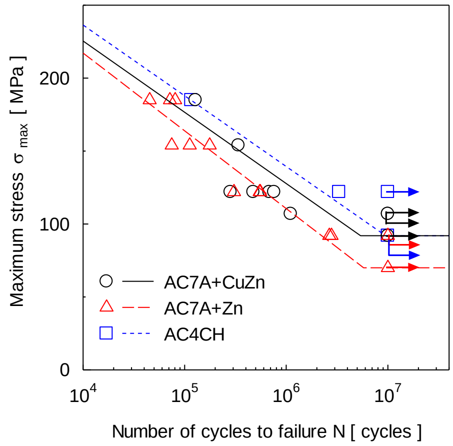

Fig. 2 S-N diagram.

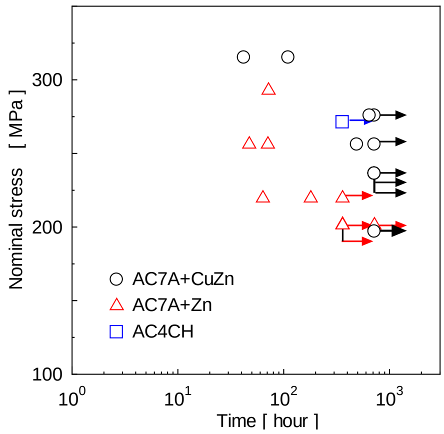

Fig. 3 Creep strength under corrosive environment

4. Conclusions

(1) The addition of Cu is effective in improving fatigue strength of Al-Mg-Zn alloy.

(2) The added Cu at grain boundary enhances the grain boundary strength, even if the hydrogen was absorbed.

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