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Influence of Elastic Stress on Age Hardening of 7075 Aluminum Alloy

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Abstract

The effect of elastic stress on the microstructure of 7075 Al alloy aged at 433 K for 1 hour was investigated using hardness testing, along with transmission electron microscopy (TEM). Results indicate that the microhardness can reach 175HV after a 25MPa elastic compressive stress aging treatment; while it decreases to 151 HV if the elastic tensile stress is applied to the specimen. TEM observation demonstrates that $MgZn_2$ precipitates formed in all experimental samples. The elastic compressive stress inhibits the formation of fine precipitates at the grain boundary.

1. Introduction

Nowadays high-strength aluminum alloys obtained by various aging treatments to different tempers are extensively used and intensively studied. The present work focuses on improving overall properties and reducing energy consumption, including refining grains, transforming the sizes and distributions of the matrix precipitate phase (MPt) and the grain boundary precipitate (GBP), controlling the grain boundary precipitation free zones (PFZ) and the GP zones[1-2] et al.

Many high-strength Al alloys are usually applied in the typical peak-aged T6 temper which can reach the highest hardness because of the appearance of finely dispersed matrix precipitation (MPt), but with low resistance to stress corrosion (RSC) for the emergence of small grain boundary precipitation (GBP)[3-4]. Increasing aging temperature (such as over-aging treatment) can be coarsen the GBP, resulting gin better RSC. However it is hard to do it without coarsening the MPt which will reduce the strength of the alloys at the same time[3,5,6]. Besides, the long aging period time and the high energy cost is the other distinct shortcoming of the T6 heat treatment. The restrogression and re-aging (RRA) treatment can not only keep the high strength of the 7075 Al alloy, but also increase its resistance to intergranular corrosion and exfoliation corrosion owing to the discontinuous distribution of the η precipitates at the grain boundary and the finely dispersed η precipitation in the interior. However, the aging treatment can not be used for large-section Al alloys due to its very short retrogression time[6,7].

As pointed out by Xu Tingdong[8,9], the segregation or depletion of alloy's solute atoms will happen in the grain-boundary under elastic stress aging heat treatment. This conclusion has used in the research of influence of impurity atom concentration in the grain-boundary on brittleness of alloys. However, there is little research report about using this method that makes alloy's solute atoms deplete in the grain-boundary to control the GBP and PFZ. The aim of this present paper is to determine the influence of elastic stress aging treatment on precipitate phase and properties of 7075 Al alloy, and the mechanism of stress aging treatment is also discussed.

2. Materials and methods

The composition of the experimental 7075 Al alloy is given in Table 1.

Table 1

Composition of the 7075 Al alloy

Z	Zn	Mg	Cu	Cr	Fe	Si	Mn	Ti	Al
Wt.%	5.85	2.57	1.50	0.21	0.16	0.06	0.05	0.02	Bal.

Table 2

Various heat treatments of the 7075 Al alloy

Aging condition	Elastic compressive stress aging	Elastic tensile stress aging	normal pressure aging	T6 aging
	433K×1h			393K×24h

Elastic stress aging experiments are carried out in two reconstructed heating furnaces (Fig. 1). And the size of the elastic tensile and compressive stress aging treated samples are 2×20×150 (mm) and 2×10×20 (mm), respectively.

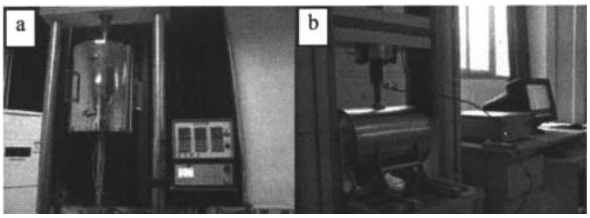

Fig. 1 The stress aging heat treatment furnaces: a) for tensile stress, b) for compressive stress

All the 2 mm thick sheet samples were solution treated at 763 K for 90 min, followed by a water quench. Subsequently, the quenching samples were aged at 433 K for 1 hour accompanied by an elastic stress of 25MPa. As shown in Table 2, the contrast experiment consists of a 433 K aging of 1 h and a 393 K aging of 24 h.

Vickers microhardness was measured on a FM-700 Hardness Tester with a load of 300 g and a loading time of 10 s. For each sample, at least 10 points were measured to obtain an average value. H-800TEM was used to conduct the TEM analysis. And the TEM samples were prepared by mechanical grinding and electropolishing in a solution of 7% perchloric acid—acetic acid.

3. Results and discussions

The isothermal aging table of microhardness for the experimental alloys aged at 433 K is shown in Fig. 2. It is found that, compared to the normal pressure aging treatment (166 HV), the 7075 Al alloy with the elastic compressive stress aging treatment has high hardness (175 HV). With the elastic tensile stress aging treatment its hardness is to 151 HV.

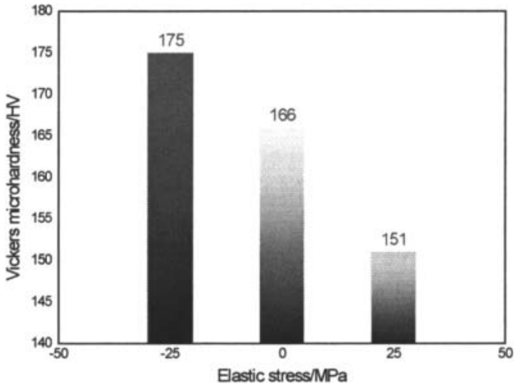

Fig. 2 Microhardness of 7075 Al alloy aged at 433 K with different elastic stress

Fig. 3 shows the TEM micrographs of samples at T6 temper, after elastic tensile stress and after elastic compressive stress aging treatment. The selected area electron diffraction pattern (SAED) is affixed in the upper right corner of micrographs. It shows that finely distributed precipitations (white arrow marker) form at the grain boundary of the T6 aging treated specimen (Fig. 3f); there is not many precipitations in the interior of grains compared to the elastic tensile stress aging treated sample, but the GBPs (Fig. 3e) grow into large size compared to the T6 aging treated specimen; however, the elastic compressive stress aging treated sample has many less precipitations in the interior of grains than the T6 sample, and there is no precipitations observed at the grain boundary (Fig. 3d). Besides, the average precipitate size (~ 100 nm) of both the elastic tensile and compressive stress aging treated samples is larger than the T6 sample (~50 nm).

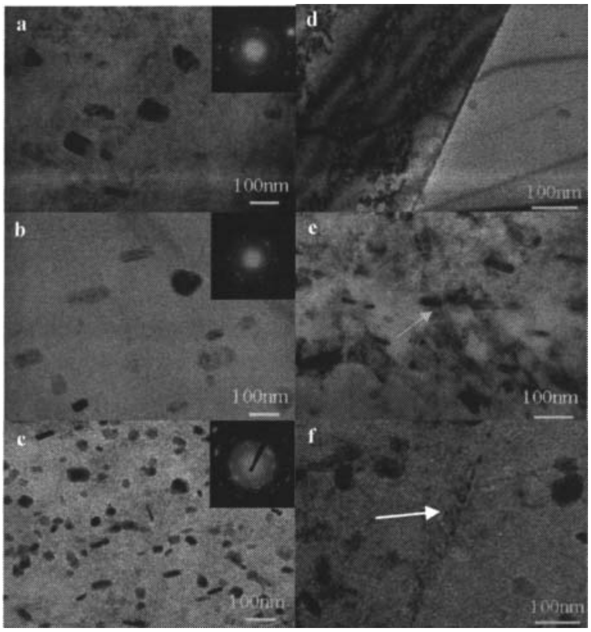

Fig. 3 Bright field TEM-micrographs of the elastic compressive stress (a, d), elastic tensile stress (b, e), T6 (c, f) aging treated samples and associated diffraction pattern.

After demarcating the selected area electron diffraction pattern, the results of phase identified show in Table 3. It demonstrates that the precipitations formed in the T6 and elastic stress aging treatment are $MgZn_2$ phase, i. e. the elastic stress aging treatment does not change in the type of precipitations.

Table 3 Comparison of the interplanar spacing of MgZn2 between the PDF card and the calculated values

$MgZn_2$		433K×1h +25MPa	433K×1h -25MPa	393K×24h
hkl	$D(Å)_{PDF}$	d (Å)	d (Å)	d (Å)
100	3.9900	—	4.097	—
110	2.6090	2.687	2.713	2.707
103	2.4110	2.489	2.463	2.501
112	2.2270	2.301	—	2.312

4. Discussion

The influence of elastic stress aging treatment on mechanical properties of 7075 Al alloy was studied in detail by hardness testing and TEM. Results indicate that the microhardness of the elastic tensile stress aging treated samples dropped by 9.0% compared to the normal pressure aging treated samples. While the elastic compressive stress aging treated samples' increased by 5.4% compared to the normal pressure aging treated samples. The TEM micrographs agreed with these results. It is notable that the microhardness of the elastic compressive stress aging treated samples has been close to the T6 temper properties, although the stress aging treatment is performed only 1 hour. Besides, the formation of precipitates at the grain boundary is apparently suppressed in the elastic compressive stress aging treated samples. This influence may be related to the segregation/dilution of the solute atoms at the grain boundary when the elastic stress is applied to the aging treated samples.

Xu believes that vacancies would be combined with solute atoms to form vacancy-solute atom complexes when elastic tensile stress exerts on the samples at low temperature. The complexes diffuse to the grain boundaries, as a result, producing an enrichment region of solute at the grain boundary. While elastic compressive stress bring about a dilution region of solute at the grain boundary due to the diffusion of complexes in the opposite direction[10,11]. The main solute atoms are Mg and Cu atoms in the solution treated 7075 Al alloy. And in the tensile/compressive stress field, they segregate/dilute at the grain boundary which leads to the difference in the distribution of precipitates between the grain boundary and interior. In macro characterization, the discrepancy reflects on the microhardness.

Conclusions

Processing by a 25 MPa elastic compressive stress aging treatment of an Al-Zn-Mg-Cu

(7075) Al alloy at 433 K for 1 hour promotes the formation of $MgZn_2$ precipitates in the interior of grains and inhibits the formation of precipitates at the grain boundary. The microhardness reaches 175 HV. If the compressive stress is replaced by tensile stress, the amount of the precipitates in the interior of grains is declined and the precipitates with large sizes form at the grain boundary. The microhardness drops to 151 HV.

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