THE AGEING BEHAVIOUR AND TENSILE PROPERTIES OF Al-Li ALLOY CONTAINING Sc

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Abstract

The ageing response of Al-1. 42Li-2. 41Cu-0. 93Mg-0. 073Zr-0. 17Sc(wt%) alloy at room temperature and 160 C was studied by hardness measurement. The room temperature tensile properties of the alloy at quenched—condition and aged at 160 C for various time were tested. The microstructure of the alloy for various conditions was observed with TEM. The results showed that the alloy had better tensile properties and the main precipitates of the alloy as quenched were the particales containing Sc, Zr, which had a coherent relation with matix. Addition of Sc in Al-Li-Cu-Mg-Zr alloy was favourable to promote the precipitation. The particales could serve as preferred nucleation sites for δ', which accelerated the ageing hardening rate at initial ageing. The main hardening phases of the alloy aged at 160 C were δ' and "composite" precipitates. The mean size of the compound precipitates was 28-32 nm. It would preclude efficiently from the intense slip localization and improve the mechanical properties of the alloy.

Introduction

Al-Li system alloys offer lower density and higher specific strength. But, the alloys are characterized by low ductility and fracture toughness, which severely limit their commercial application.

It suggested that a primary factor in low toughness was slip localization which occured as a result of work-softening on certain slip—planes during deformation. The shearable nature of δ' phases and consequent decreased resistance to dislocation slip on planes containing the sheared δ' were considered to be responsible for the behaviour. The studied results showed that addition of some elements in the alloys such as Zr [1], Ti[2], Sc[3] would form "compound" precipitates. The generally non-shearable nature of the compounds would preclude from the intense slip locazation and improve the mechanical properties of the alloys. Sc would combine with Al to form Al_3Sc, which acts as a core of δ' precipitating to form two phases precipitate Al_3Li/Al_3Sc. L. I. Kaygordova[4] studied the effect of Scanium in Al-Li-Cu and Al-Li-Mg alloys. the effect of Sc on morphology and kinetics of solid solution decomposition for

Al-Li alloys have also been studied[5]. However, The effect of Sc in Al-Li-Cu-Mg-Zr alloys have been less studied. The present work intends to examine the effects of Sc addition on ageing response and the microstructure characteristics of Al-Li-Cu-Mg-Zr alloy.

Experiment Procedure

The composition of the alloy was Al-1. 42Li-2. 41Cu-0. 95Mg-0. 073Zr-0. 17Sc (wt%). The ingot with thickness 20mm was homogenized, hot and cold rolled into sheet with thickness 1. 52mm. The sheet was solution treated at 525°C for 40min, quenched into ambient water and followed by aged at room temperature and 160°C for various periods of time.

The hardness measurement was carried out with loading 60kgf by using HW-187. 5 type tester. The tensile properties of the alloy were tested by electron tensile machine. TEM samples were prepared by mechanical grinding and twin jet polishing in a solution of 1 part HNO_3 and2 parts methanol. The microsturctures of the samples for various conditions were observed with Hitachi-800 tranmission electron microscopy (TEM).

Results and Discussion

Ageing Hardening Curves

The changes of the hardness(HRF) with ageing time at room temperature and 160°C are shown in Fig. 1. The alloy containing Sc aged at room temperature had significant

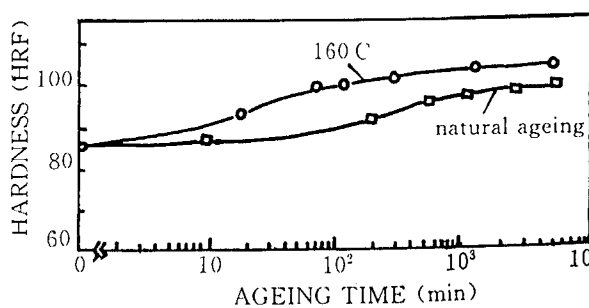

Fig. 1 Ageing Hardening Curves of the Alloy Containing Sc

ageing hardening effect. Hardness values were evidently increased after natural ageing for 200 min. The hardness values increased more quickly with time during ageing at 160°C, compared with other Al-Li alloys without Sc. The hardness value was 100. 3 HRF aged at 160°C for 300min and 102. 9 HRF for 3000min and countiued to increase with age time. The hardness values were still not decreased after aged at 160°C for 4000min (previous work showed that the hardness values were not decreased even aged at 190°C for 4000min), which showed that the alloy had good themal resistance during ageing. With prolonging aged time, the hardness value retainted about 107.8HRF for 5500min.

Tensile Properties

The tensile properties of the alloy at qenched—condition and aged at 160℃ for various

Table 1 Tensile Properties of the Alloy

ageing condition	σ_b(MPa)	$\sigma_{0.2}$(MPa)	δ(%)
as quenched	424.0	305.8	—
160℃/2h	451.2	340.8	19.2
160℃/20h	488.1	390.9	14.9
160℃/70h	487.6	391.0	13.0

time are given in table 1. The tensile properties were correlative well with the hardening behavior. Ultimate tensile strengh and Yield strength gradually increase with ageing time but elongation droped. For long time(70h), the data of UTS and YS were still maintained. UTS, YS and El of the samples aged at 160℃ for 70h were 487.6 MPa, 391.0 MPa and 13.0(%) respectively.

Microsturcture

The microstructure of the alloy under quenched condition is shown as Fig. 2, which in-

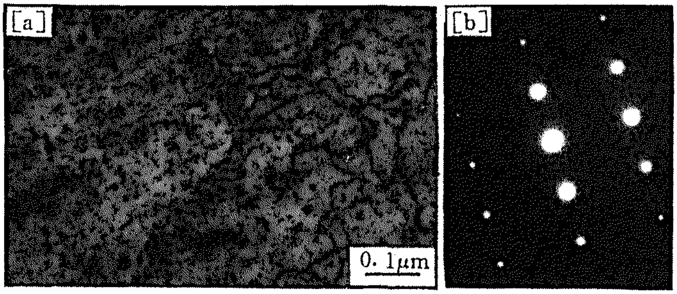

Fig. 2 Microstructure of the Alloy as Quenched Condition
(a) coherent precipitates and dislocations (b) superlattice spots

dicated that a large amount of particales precipitated uniformly in matrix. The precipitating particales, which were of a spheric morphology, had coherent relation with Al matrix in term of the diffraction patten. It was well known that the alloy containing Zr, Sc precipitated Al_3Zr, Al_3Sc phases resptively. I. N. Fridlyander[6] found β′ -

$(Al_3Sc_xZr_{(1-x)})$in 1420 alloy containing 0. 18wt% Sc. So, the particales in present alloy would be Al_3Sc, Al_3Zr or $Al_3(Sc_x Zr_{(1-x)})$. It was very difficulty to distiguish these particales by diffraction patten because the precipitates had the same crystal structure and very near the parameters of crystal lattice. There were more precipitates in Al-Li-Cu-Mg-Zr alloy containing Sc. Addition of Sc in Al-Li-Cu-Mg-Zr alloy would promote more precipitates compared with that of only addition of Zr in alloy. The area fraction of the precipitation was about $1.0 \times 10^8/mm^2$. It was thought that Al_3Sc particales precipitated during solution treatment and hot rolled procedure[6]. At present work, the decomposite product δ' in the alloy as quenched could not be observed under dark field condition. The reasons would be that the alloy contained only 1. 42wt%Li, which were within solution limite and Sc-vacancy, Zr-vacancy band energy were very near compared with Li-vacancy (0. 25+0. 03 ev)[7,8], which reduced the free vacancies concentration after quenched and retained the formation of δ' phases during quenching and natural ageing[7]. The harden effect of natural ageing would be considered to relation to GPZ or other precipitates such as θ'' formed in the alloy containing2. 41wt% Cu during natural ageing.

The microstructures of the alloy aged at 160 C are shown in Fig. 3, which showed that there existed two types of precipitates in matrix. One is a very small white

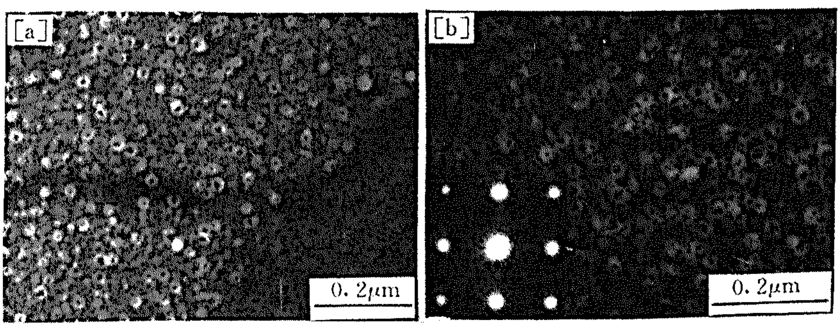

Fig. 3 δ' and Complex δ'/β' Phases
(a) 160 C/2h (b) 160 C/70h

particales δ' (Al_3Li). The other is the "complex" phases Al_3Li/Al_3Sc et al. They were main hardening phases of the alloy aged at 160 C. The data about the parameters of the precipitates are provided in Table 2, which indicated that the area density of complex phases did not evidently change with ageing time. But the sizes of the particales could increased lightly. The distances between the compound particales were about 0. 04 μm. The size of compound precipitate (28-32nm) were bigger than 17nm, which would change the deformation mechanism from shearable to non-shearable fasion[8]. So, the compound precipitates improved the properties of the alloy. The formation mechanism of compound phases would not be quite understood at present, it was thought, which associated to reduction in interfacial energy resulting from precipitation at a pre-existing interface compared to homogeneous nucleation in matrix. Kim, et al. [9] reported that the dislocations surround Al_3Zr particales would promote Li diffuse process accelerating the formation of the compound precipitates.

Table 2 The Data of δ′ and Complex (δ′/β′) Phases

Condition		mean size of δ′ (nm)	mean size of δ′/β′ (nm)	area fraction of δ′/β′ (mm^{-2})
160℃/2h	(in matrix)	12.2	28.0	5.0×10^8
	(at boundaries)	13.8	28.9	5.7×10^8
160℃/73h	(in matrix)	14.0	28.4	6.5×10^8

But the influence of dislocations on compound precipitating would not be found with TEM in the alloy aged at 160℃ after stretched 8%.

Conclusions

1. Al-Li alloy containing Sc has evidently natural ageing hardening response. For the samples aged at 160℃, ageing hardening rate increassed more quickly compared with other Sc-free Al-Li alloy.
2. The main hardening phases of the alloy aged at 160℃ were complex phases and δ′ phases. Addition of Sc in Al-Li-Cu-Mg-Zr alloy was be favourable to promote the precipitating and the more particales containing Sc or Zr have been be found under quenched condition. A large amount of complex phases with 28-32nm would prevent or reduce dislocation slip on planes and improve the properties of the alloy.
3. The alloy had better tensile properties. UTS, YS and EL of the sample 160℃ for 20h were 488.1 MPa, 390.9MPa, 14.9 respectively. With prolonging aged time (70h), the data were still retainted.

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