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Original Research Article

Effect of solution treatment on microstructures and mechanical properties of 2099 Al–Li alloy

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ABSTRACT

The influence of the solution treatment on microstructures and mechanical properties of 2099 Al–Li alloy was investigated by means of optical microscopy, scanning electron microscopy, transmission electron microscopy and tensile properties measurement. With increasing solution temperature, the quantity of primary particles in the alloy decreased, and the degree of recrystallization gradually increased, leading to softening of solution treated alloy. Dissolution of primary particles in the solution treatment process promoted δ' and T_1 phases to precipitate during sequent aging treatment resulting in increase of strength. The number of T_1 phases increased to peak value when the alloy was solution treated at 540 °C because almost no further dissolution of Cu-containing particles occurred at higher temperature. However, exorbitant solution temperature caused the drastic increase in the size and quantity of recrystallized grains that softened the alloy. Thus, mechanical properties of aged alloy were determined by two mechanisms: precipitation strengthening and solution softening. Compared with solution temperature, solution time had less effect on microstructures and mechanical properties of alloy. The suitable solution treatment for 2099 Al–Li alloy was 540 °C for 1 h, treated by which the yield strength of the aged alloy was 604 MPa with the elongation of 7.9%.

1. Introduction

The third-generation of aluminum–lithium (Al–Li) alloys has been developed over the last decade, targeted towards applications in the aerospace industry [1–3]. These materials offer substantial improvements in structural efficiency, fuel saving and payload in aerospace, owing to their excellent comprehensive properties, such as lower density, higher elastic modulus, more desirable fatigue and damage tolerance behavior, and higher specific strength compared with traditional aluminum alloys [4–6].

Al–Li alloys are one of the aging hardening aluminum alloys. To take advantage of the precipitation hardening reaction, it is necessary first to produce a supersaturated solid solution by solution treatment. The purpose of solution treatment is to put the maximum amount of precipitation hardening solutes [7–9] such as Cu, Li, Mg and Ag into the solid solution in the matrix. Nominal commercial, the processing parameters (temperature and time) of solution treatment are mainly determined by the chemical composition and dimension of alloy products. During solution treatment, the soluble primary particles which are formed in the

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solidification process can dissolve into the matrix. At a higher solution temperature, the dissolution of soluble primary particles is more sufficient. However, Overheating may cause formation of surface blisters, recrystallization, and eutectic melting in some alloys [10–14]. On the other hand, underheating will lead to incomplete solutionizing prior to precipitation. Therefore, the investigation of the effect of solution treatment is necessary and beneficial to get comprehensive properties of Al–Li alloys. The present work was undertaken to investigate the effect of solution treatment on microstructures and mechanical properties of 2099 alloy. These results can give indispensable information for optimizing the properties of 2099 alloy.

2. Experimental

The 2099 alloy (Table 1) was prepared by liquid metallurgy route in an electrical resistance furnace. The permanent water-cooled cast iron mould was used to shape the alloy in the form of 100 mm in diameter, 230 mm long cylindrical casting. The as-cast alloy was subjected to two-step homogenization treatment (510 °C/12 h+530 °C/36 h) in the salt bath. After homogenization treatment, the alloy was annealed at 470 °C for 4 h in an air furnace, and subsequently extruded into cylindrical rod of 16 mm diameter at 470 °C. The extruded rod was machined into tensile samples with gauge dimensions of 6 mm in diameter and 40 mm in length. These samples were exposed to six different solution treatment schedules: STS1 (520 °C/1 h), STS2 (530 °C/1 h), STS3 (540 °C/1 h), STS4 (540 °C/4 h), STS5 (550 °C/1 h) and STS6 (560 °C/1 h). During solution treatment, samples were directly immersed into a salt bath at the set temperatures. After solution treatment, these samples were rapidly quenched into water, stretched to 2.5% at room temperature, and then subjected to two-step aging treatment (121 °C/12 h+152 °C/48 h).

Room temperature mechanical properties were performed on MTS 858 testing machine in a displacement controlled mode at a displacement rate of 2 mm/min. Three samples per condition were tested. An extensometer attached to the sample gauge was used to determine strain and total elongation. Leica EC3 metallographic microscope was employed for metallographic microstructures analyses. The samples for metallographic observation were prepared through a conventional mechanical polishing and followed by etching with Keller reagent (2.5 mL HNO_3, 1.5 mL HCl, 1 mL HF and 95 mL H_2O).

Table 1 – Chemical composition of 2099 alloy (wt%).

Cu	Li	Mg	Zn	Mn	Ti	Zr	Al
2.73	1.68	0.32	0.72	0.34	0.05	0.10	Bal

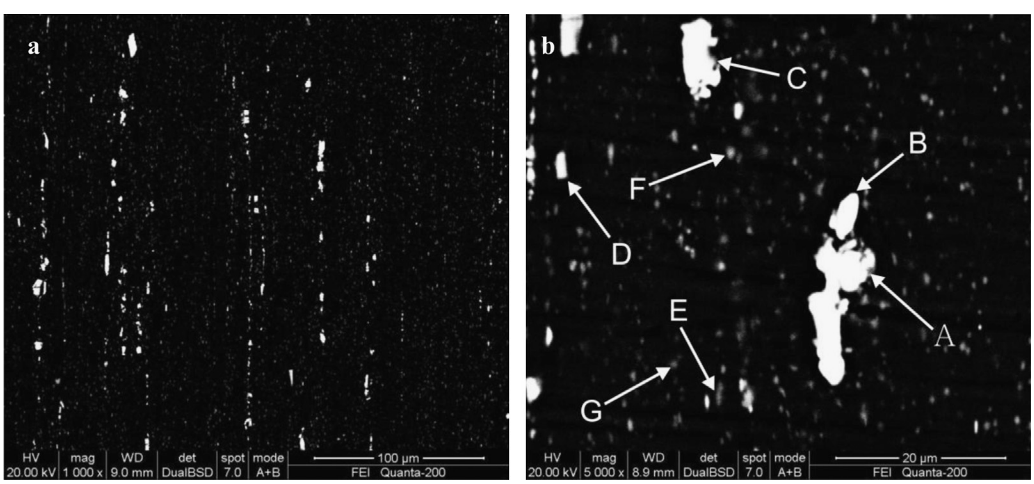

Fig. 1 – SEM micrographs of as-extruded alloy: (a) 1000 × ; (b) 5000 × .

Table 2 – EDX results of the primary particles in the as-extruded alloy (wt%).

Point	Cu	Mn	Fe	Al
A	28.56	1.59	10.48	59.37
B	29.01	2.37	11.47	57.15
C	26.68	2.01	9.01	62.22
D	5.97	5.07	9.82	79.82
E	3.54	3.07	5.82	87.58
F	9.61	0.51	0.41	89.47
G	8.73	2.79	0.77	87.71