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Kozina, Franjo; Zovko Brodarac, Zdenka; Petrič, Mitja

INFLUENCE OF SOLUTION HARDENING ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF Al-2.5 Mg-0.7Li ALLOY

Franjo Kozina[1], ZdenkaZovko Brodarac[1], Mitja Petrič[2]

[1]*University of Zagreb Faculty of Metallurgy, Alejanarodnihheroja 3, Sisak, Croatia*
[2] *University of Ljubljana, Faculty of Natural Sciences and Engineering, Aškerčevacesta 12, Ljubljana, Slovenia*
**Corresponding address: fkozin@simet.hr*

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ABSTRACT

Although utilization of lightweight aluminum alloys in transportation industry reduced harmful emissions and improves fuel economy, their further application is limited by low stiffness, low Young modulus and sensitivity to elevated temperatures. It was found that specific strength properties of aluminum alloys can be improved by Li additions. The beneficial effect is achieved by precipitation of hardening Al_3Li precipitate.

The microstructural and mechanical properties of Al-2.5 Mg-0.7 Li alloy were investigated in as cast and solution hardened condition. The microstructure constituents and thermo-mechanical properties for both conditions were determined and compared.

1. Introduction

Dependence of environmental conservation on transportation industry placed automotive manufacturers under great pressure to reduce fuel consumption and emissions. Weight reduction is considered to be the most cost-effective option to reduce harmful emissions and improve fuel economy [1]. The Al alloys were introduced as a response to the weight reduction demand. The downsizing effect of foundry Al-Si, Al-Si-Cu, Al-Si-Mg alloysis achieved by precipitation of complex intermetallic phases [2].

However, the sensitivity to elevated temperatures[3], low Young modulus of elasticity and additional weight savings indicated the need for chemical composition redesign. Modifying chemical composition with Liadditions enables direct weight savings, improved elastic modulus and specific strength properties. The additions ofLi enable the formation of potent hardening precipitates, in particular metastable Al_3Liprecipitate [4].

An Al-2.5 Mg-0.7 Li alloy was investigated in as cast and solution hardened condition in order to compare microstructure and mechanical properties. The microstructure in as cast condition consists of following constituents: primary aluminum (α_{Al}), intermetallic phases based on Li (metastable Al_3Li and stabile AlLi phases), ternary phase(Al_2LiMg) and secondary eutectic (Al_3Mg_2).Since the hardening is mainly achieved by precipitation of metastable Al_3Li phase, solution hardening was used in order to dissolve other intermetallic precipitates and bulk α_{Al} matrix. Identification of solution hardening parameters was performed based on thermodynamic behaviour of an alloy.

2. Materials and methods

The Al alloy was synthesized by melting in the induction melting furnace under protective atmosphere of argon. The synthesized alloy was cast into a permanent steel mold without protective atmosphere.

In order to identify temperatures significant for phase transformation and precipitations, Simultaneous Thermal Analysis(STA) was applied. The temperature of solution hardening wasestimated on the base of Differential Scanning Calorimetry (DSC) results.The micro constituents in as cast condition were identified using X-Ray Diffraction (XRD).

Number of grains per unit area was determined for samples in in as cast condition, after solution hardening and after compression testing. Olympus SZ 11 with digital camera Promicra was used.

Thermo-mechanical properties were measured using Gleeble 1500D machine. Samples 1 and 2 were tested in as cast condition and at room temperature. The samples 3 and 4 were solution hardened and tested at elevated temperatures. The micro-hardness was measured on samples in as cast condition and after solution hardening using LEICA VMHT 302801 machine.

3. Results and discussion

The heat treatment regime consisted of solution hardening at 520°C followed by quenching in water and artificial aging at 190°C during thermo-mechanical testing.

The number of grains pre unit area (N_A) is given in Table 1.

Table 1. Number of grains per unit area [grains/mm]

Condition	Before deformation	After Deformation
As cast	0,51	0,37
Solution Hardened	0,64	0,57

The solution hardening led to the recrystallization of primary microstructure. The number of grains was reduced respectively. During thermo-mechanical testing of primary as cast microstructure, the number of grains significantly increased. In contrary, heat treated microstructure was not deformed at all during the same testing parameters.

The microstructure of samples before and after thermo-mechanical testing is given in Fig.1

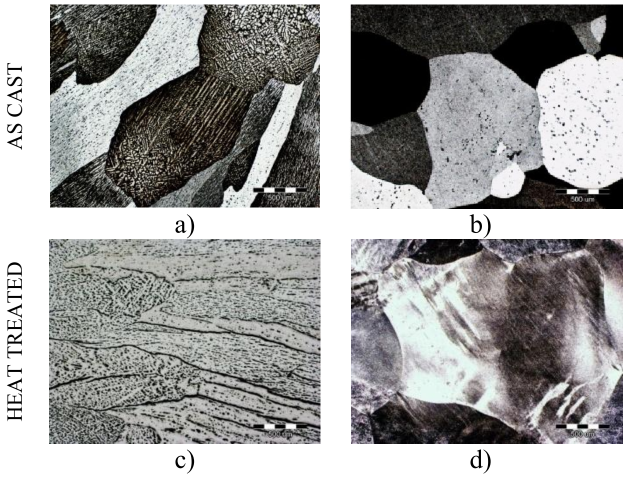

Fig. 1. The microstructure of:a) sample 1 - as cast;b) sample 2 – heat treated, c) sample 3 – as cast, thermo-mechanically tested, d) sample 4 – heat treated, thermo-mechanically tested.

The thermo-mechanical testing of as cast microstructure (Fig.1a) led to the significant texture development (Fig.1c). Thermo-mechanical testing of solution hardened and aged microstructure (Fig.1b) did not causeanydirected microstructural change (Fig.1c).

The results of thermo-mechanical testing are given in Table 2.

Table 2. The results of thermo-mechanical testing

Sample No.	Strain rate, mm/min	Re, MPA	Rm, MPa	Deformation, %
1	100	375.02	543.70	46.4
2	230	155.17	289.89	41.5
3	100	180.32	273.47	58.2
4	100	178.20	260.17	55.3

The sample 1 had the highest tensile and yield strength values. Increasing strain rate up to 230 mm/min caused the drop in both values (sample 2). Samples 3 and 4 had a significantly lower strength properties compared to the first two samples. It is assumed that higher strength properties in as cast condition occurred as a result of Al_3Li precipitates. These Li based intermetallic precipitates interact with dislocations progressing from the grain boundaries. The assumption is supported by texture development during thermo-mechanical testing (Fig.1b). The solution hardening caused dissolution of Al_3Li precipitates enabling free movement of dislocations. Furthermore, the mobility of dislocations was increased due to the increase in testing temperature.

The micro-hardness measurement results are shown in Table 3.

Table 3. Results of Micro-hardness measurements

Condition	HV		
As cast	92.0	92.4	93.4
Solution Hardened	102.5	103.2	103.3

The solution hardening led to the increase of micro-hardness values.

4. Conclusions

The influence of solution hardening on microstructure and mechanical properties of Al-2.5 Mg-0.7Li alloy wereinvestigated. The solution hardening was performed in order to inducethe metastable Al_3Li hardening precipitation and dissolving of ternary Al_2LiMg intermetallic phase and secondary eutectic Al_3Mg_2 phase and their incorporation in α_{Al} solid solution.

However, samples tested in as cast condition showed the higher strength properties (Table 2). The texture developing during deformation was a result of interaction between Al_3Li precipitates and dislocations progressing from the grain boundaries (Fig.1c). Although solution hardening has had a beneficial influence on micro-hardness values (Table 3), while at the same time having a weak influence on strength development. During deformation dislocations were moving freely, without limitation due to precipitations, resulting in low strength properties (Table 2). This is supported by lack of texture after deformation (Fig.1d).

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