STUDY OF THE STRUCTURE AND PROPERTIES OF 1420 ALLOY MODIFICATIONS FOR SHEETS

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Abstract: New modifications of 1420 weldable and corrosion-resistant alloy with the lower lithium content and additional alloying by scandium and other elements were investigated. The excessive δ-phase (AlLi) was revealed with the lower content of S_1-phase (Al_2MgLi) in the structure of some alloys, which didn't complied with the Al-Mg-Li triple state diagram. These alloys were distinguished by higher ductility and fracture toughness. The sheets of these alloys were characterized by the essential anisotropy of elongation, yield strength and ultimate strength due to Sc or Sc and Zr modification. The effort was made to minimize anisotropy in sheets by optimizing the rolling technological parameters, correcting the zirconium and scandium content and by additional microalloying.

Keywords: *microalloying, anisotropy, grain structure, fracture toughness*

Introduction

The reduced technological ductility and fracture toughness are the barrier to the wide application of weldable 1420 low-density and corrosion-resistant alloy in the aircraft constructions. Besides, similarly to all Al-Li alloys, the 1420 alloy possesses the insufficient thermal stability during the sun heating (85°C, 1000 hours).

The AL-Mg-Li alloys, containing from1,5 to 2% Li, from 5 to 6% Mg and additionally microalloyed with Zr, Sc, Mn and Cr, were investigated with the goal of improving these properties. The alloys are in the $\alpha+S_1(Al_2MgLi)$ - phase region of Al-Mg-Li state diagram. The basic strengthening phase in them is $\delta'(Al_3Li)$.

Material and Experimental Procedures

Ingots of 70 mm in diameter were produced of alloys with different compositions. These ingots were homogenized at the temperature of 500°C, 10 hours with the following cooling at the rate of 30°C/hour. Then the bands with the cross section of 15x60 mm were extruded of ingots after their heating at 360-380°C for not less, than 2 hours. Extruded bands were firstly hot rolled to 4 mm in the transverse direction then cold-rolled down to 2,5 mm.

The study of the grain structure in sheets was carried out by X-ray photographic method in

URS chamber with the use of URS-2,0 apparatus. The research of the phase composition in the studied alloy specimens was performed by means of DRON-3 diffractometer in copper monochromatized radiation. The goniometric unit, ensuring the simultaneous specimen rotation and swinging, was used during the X-ray surveying. In order to evaluate the relative change of δ'(Al_3Li) and δ - (AlLi) intermetallic phases quantity, the line intensity of both the δ' superstructural phase (110) – aluminium (200) and δ-phase (111) – aluminium (111) were compared.

The fractographic analysis was carried out by means of JSM-840 electron scanning microscope with the magnification from x10 to x 5000.

Results and Discussion

Sheets of the studied alloys, air-quenched from the temperature of 460°C and peak-aged at 165°C, 16 hours, exceed the 1420 alloy in yield strength, but they possess the high anisotropy of properties, though Li content decrease slightly improves the situation in alloys (Table 1).

Table 1. Al-Mg-Li -0,09%Zr -0,08%Sc sheets tensile properties

Alloy No	Direction	UTS, MPa	YS, MPa	Elongation, %
1 Al-1,96Li-5,2Mg	L	477	382	4.5
	LT	524	403	7.5
	45	367	268	14.5
2* Al-1,96Li-5,2Mg	L	474	373	3.5
	LT	517	384	8.5
	45	476	346	10.5
3 Al-1,57Li-6,02Mg	L	430	316	10.5
	LT	461	343	9.5
	45	445	310	16.0
4* Al-1,57Li-6,02Mg	L	469	360	6.5
	LT	524	375	10.0
	30	491	357	10.5
	45	461	317	15.5
	60	455	314	15.5

* - 2th and 4th alloys contain some microadditions

The alloys with the completely recrystallized structure have no this problem [1]. However, the production of such structure for Al-Mg-Li alloys is the sufficiently complicated technological problem. It is known from the experience of 1420RS sheet production by the structure heterogenization and the high deformation degree up to 50% during cold rolling [2].

This problem becomes much more complicated for the studied alloys, which are additionally modified with elements-antirecrystallizers Zr and Sc. The use of heterogenizational annealing (overageing at the temperature of 395-400°C) prior to the cold rolling and the substitution of Zr and Sc for Mn and Cr and also other microadditives allowed to produce the grained structure with various recrystallization degree in sheets and, hence, the anisotropy decrease (Table 2).

Table 2. Al-Mg-Li sheet properties depending on the grain structure

Alloy No	Sheet structure	Direction	UTS, MPa	YS, MPa	Elonga-tion, %
5 AlMgLiZrSc	Nonrecrystallized, deformation texture	L	469	360	8
		LT	500	380	10
		45	470	339	15
	Polygonized	L	430	248	12
		LT	458	345	14
		45	418	293	24
6 AlMgLiMnCr	Nonuniform recrystallization , initial stage	L	432	260	9
		LT	427	250	11
		45	425	227	18
7 AlMgLiMnCrSc	Completely recrystallized structure	L	420	234	15
		LT	426	248	15
		45	400	220	16

However, the anisotropy decrease is followed by a considerable reduction of strength properties. The properties, pointed in Table 2, were obtained for sheets, air-quenched from 460°C and aged according to the staged ageing, ensuring the high corrosion resistance and low alloy sensitivity to the long-term low-temperature heating (LLH).

The best combination of strength properties and ductility and also fracture toughness and fatigue crack growth rate (FCGR) is achieved during this ageing for sheets with the completely nonrecrystallized structure. In particular, for alloy no. 5 with the nonrecrystallized structure when testing compact specimens of 100 mm in width before and after heating at 85°C, 1000 hours the K_{C0} values are equal to 55-66 MPa$\sqrt{m}$ and 52-55 MPa$\sqrt{m}$, respectively. In case of this alloy but with the polygonized structure the fracture toughness (K_{C0}) values are 47-50 MPa$\sqrt{m}$ before and after heating at 85°C, 1000 hours.

Besides, the δ (AlLi)–phase with lower quantity of S_1 (Al_2MgLi) was revealed in some of the discussed alloys, when studying the phase composition in quenched state from 460°C and after quenching from the heterogenizational annealing temperatures (320, 360, 400°C).

The relative quantity of δ-phase is increased with raising the heating temperature for quenching (Table 3).

Table 3. Relative line intensity (110) of δ′(Al_3Li) strengthening phase and (111) of δ (AlLi) phase in as-quenched and as-aged alloy

Temperature, °C	I (110) δ′ / I (200) Al	I (111) δ / I (111) Al
320	0,23	0,22
360	0,50	0,16
400	-	0,22
460	1,5	0,5

These alloys are characterized by higher fracture toughness, as compared to 1420 alloy. The specimen fractures were studied after testing with the determination of FCGR and K_{C0}. It was showed the later initiation of fatigue striates and the more long-term stage of the uniformly accelerated development of fatigue crack in these alloys, as compared to 1420 (Fig.1 a, b) and the tougher fracture in the zone of the final fracture stage (Fig.1 c, d).

Conclusions

1) The best set of mechanical properties and fracture toughness was obtained for sheets of Al-Mg-Li-Zr-Sc alloys with the nonrecrystallized structure.
2) It was stated that alloys containing δ-phase with the lower content of S_1–phase possess the improved ductility and fracture toughness.

References

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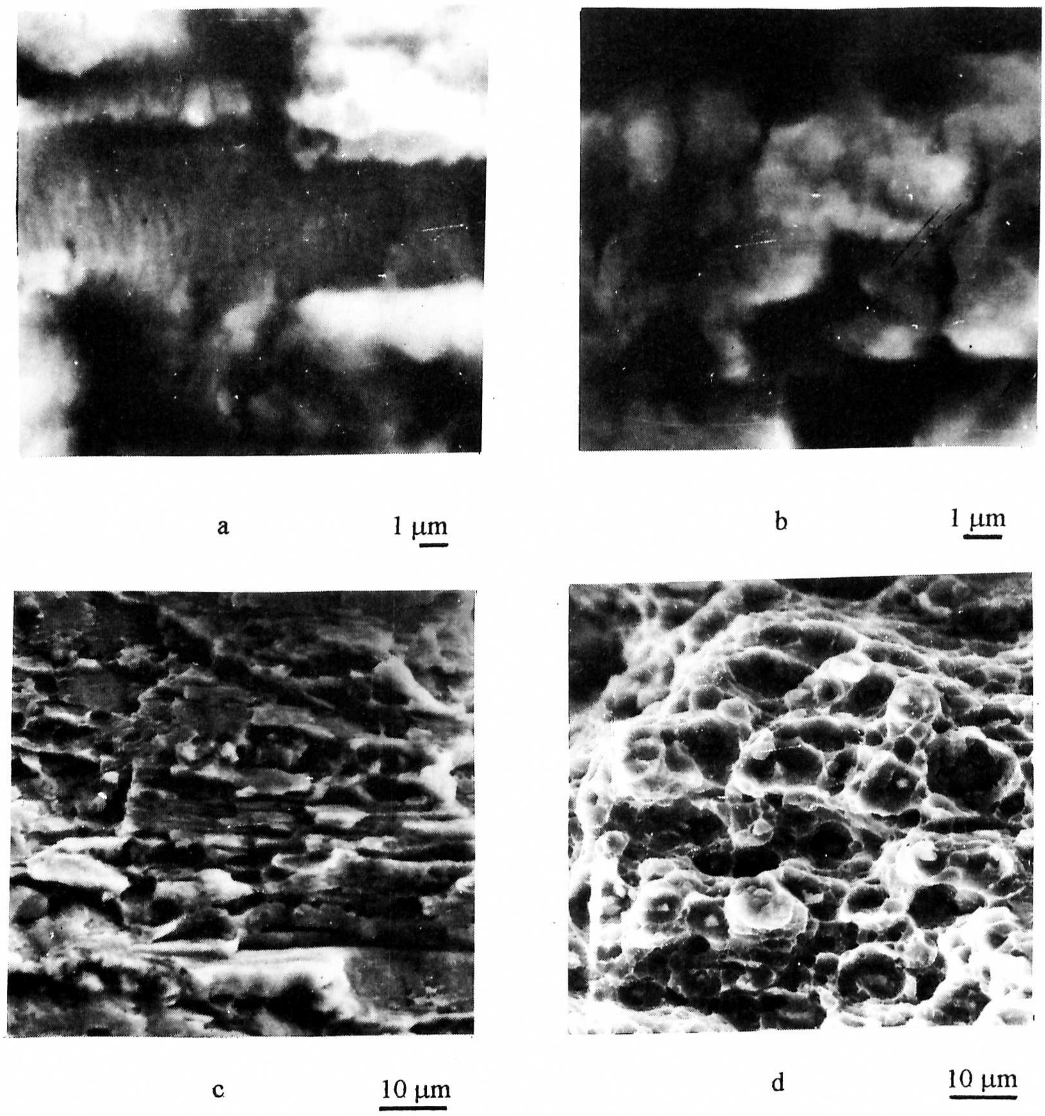

Fig. 1. Fracture surfaces in 1420 (a, c) and new alloy (b, d): the zone of 1,5 mm crack (a) and 3,5 mm (b); the zone of the final fracture stage (c, d).