PROPERTIES OF NEW Al-Li-Mg ALLOY

J.N.Fridlyander[1], N.I.Kolobnev[1], L.B.Khokhlatova[1], E.Loechelt[2], P.-J.Winkler[3], T.Pfannenmuller[3].

1) All-Russian Institute of Aviation Materials, Moscow, Russia.

2) DASA-DA, Bremen, Germany

3) Daimler-Benz Research and Technology, Munich, Germany

Abstract: Thermal stability of new weldable and corrosion resistant Al-Mg-Li alloy is provided by optimizing the chemical composition and heat treatment after aging and exposing for up to 1000h at 85°C. The sheets of the pointed new alloy meet the requirements for statical strength and ductility, characteristics of cyclic cracking resistance and fracture toughness imposed upon materials used for fuselage skin of passenger aircraft.

Keywords: *thermal stability, stage-aging, fine-dispersed* δ'-phase

It's the most advisable to use the aluminum-lithium alloys (ALA) in flying vehicles where the factor of weight is of great importance. The weight saving of the structure is possible not only by the use of light Al-Li-alloys but also by means of substitution of a riveted structure for a welded one. The use of Al-Li-alloys in the riveted structures provides a weight saving by 8-12% and in the welded structures up to 25%. It gives an opportunity to increase a load-carrying capacity, to save fuel and to improve the other tactico-technical characteristics of flying vehicles.

The weldable corrosion-resistant Al-Li-Mg-alloys possess the smallest density. In Russia the 1420 alloy was developed on the basis of this system. This alloy found its application not only in aircraft riveted structures but also in the welded cockpit and fuel tanks [1].

The use of Al-Li-Mg-alloys for the welded fuselage skin of new generation airbuses is of the great interest. To solve this problem it was necessary to develop a new alloy with improved characteristics of fracture toughness and resistance to cyclic loads and also with increased technological plasticity providing the production of cold-rolled sheets of width up to 2600 mm.

One of the basic materials of riveted fuselage structures for different aircraft types are the Al-Cu-Mg alloys such as D16 or 2024. There is an experience of many years concerning the application of these alloys in aircraft operated in all climatic zones. For a number of characteristics the 2024 and D16 alloys comply with the modern requirements of designers with the exception of corrosion resistance. Therefore the new corrosion- resistant weldable 1424 alloy with density of 2520 kg/m^3 offers promise as a material for fuselage structures [1].

The basic problems in developing the 1424 alloy were the improvement of thermal stability at long-term low-temperature heating (LLH) and decrease of mechanical anisotropy in different directions with respect to the sheet rolling direction.

During the long-term up to 1000-hour heating at 85°C (LLH) a decrease of ductility and fracture toughness with simultaneous improvement of strength properties is observed in the Al-Li alloys. This phenomenon is being associated with the additional fine-dispersed strengthening δ'(Al_3Li) - phase precipitation that is due to high residual supersaturation of the solid solution with lithium after artificial aging [2,3]. The high dispersion of δ'-phase particles precipitated during the LLH makes them difficult to detect by the transmission electron microscopy [3].

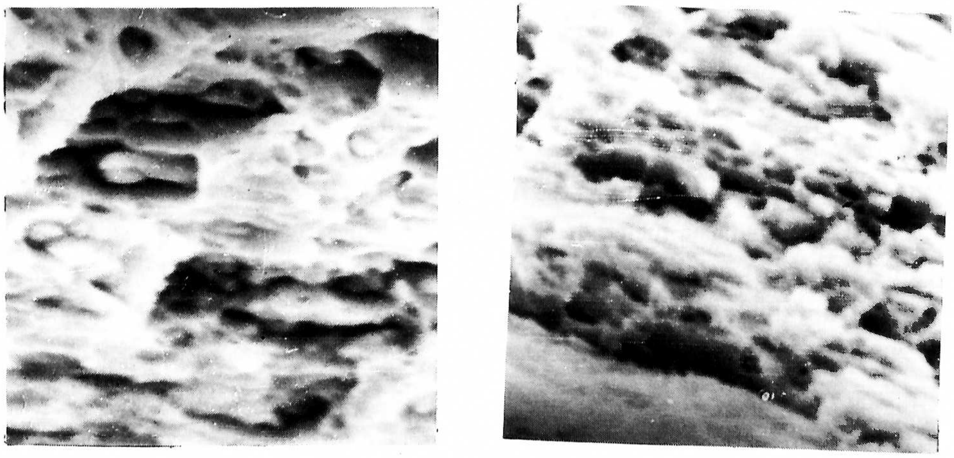
At first the recommended strengthening heat treatment for the 1424 alloy included air quenching from temperature of 460°C for the purpose of providing the high corrosion resistance and two-stage artificial aging at the temperatures of 80-125°C for the purpose of providing high characteristics of fracture toughness and crack resistance.

There are the master strengthening δ' -phase, Al with Zr and Sc dispersoids, excessive S_1 (Al_2MgLi) and δ (AlLi)- phases in the alloy after such treatment .

An increase of δ'-phase volume fraction in the 1424 alloy during LLH is confirmed by results of X-ray diffraction analysis, fractographic investigation of fractures and it is followed by the conductivity increase of 4, 0-5,5%.

By means of X-ray analysis from the separation of $(422)_\alpha$ and $(422)_{\delta'+\alpha}$ doublets and from the change of $(110)_{\delta'}$ and $(200)_\alpha$ line intensity it was established that δ'-phase volume fraction after LLH approximately increased by 3-6%. Apparently, it occurs not only at the expense of dispersed particles precipitated during the LLH but also by the size increase of particles formed during the artificial aging [3].

The investigation of fractures surfaces of the tensile specimens and final fracture zone of specimens on K_{CO} tests showed the dimple tearing – off failure (Fig.1, 2). After LLH the dimples



a 10 μm b 10 μm

Fig.1. Fractographs of tensile specimens before LLH (a) and after LLH (b)

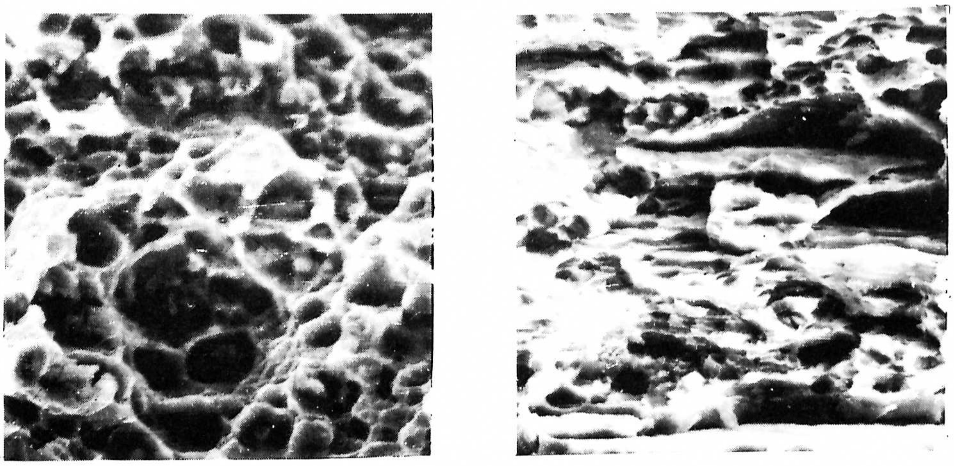


Fig.2. Fractographs of K_{CO} specimens before LLH (a) and after LLH (b)

became smaller and the square of areas with small-sized dimple relief increased that was apparently caused by the presence of strengthening phase dispersed particles.

For the purpose of increasing the thermal stability of 1424 alloy during the LLH the artificial aging has been developed which consists of the used two-stage regime and additional third stage at $T_1 < T_2$ and $T_2 > T_3$. This aging provides the additional δ'-phase precipitation, the decrease in the solid solution residual supersaturation degree and the improvement of property stability (Table 1).

Table 1. Tensile properties 1424 sheets 1,6 mm thick before and after LLH
(after air quenching from 460^{O}C, three-stage aging)

Tensile properties	Direction	Before heating	After heating 85^{O}C, 1000ч
UTS, MPa	L	515	520
	LT	520	525
	45^{O}	470	480
YS, MPa	L	360	365
	LT	370	380
	45^{O}	295	305
Elongation, %	L	8	7
	LT	16	14
	45^{O}	26	25

In this case after the LLH the fracture toughness decreases is no more than 5-6%. K_{CO} values for specimen 400 mm width are 90 and 85MPa$\sqrt{m}$ before and after LLH, respectively.

Practically the considerable anisotropy, especially for elongation, is typical for all Al-Li – alloys. Substantially, the anisotropy becomes apparent on sheets with lower values of elongation in longitudinal direction. The most probable reason of the anisotropy are the deformation texture and deformation localization in shear bands as a result of dislocations planar slip during the cold rolling [4]. The appearance of similar slip bands is also possible during the hot rolling, as in the case of lower temperature at its closing stage.

The production of sheets with isotropic properties is possible by forming the recrystallized structure with minimum grain shape anisotropy that can be achieved at high deformation degrees and at high heating temperatures before final solid solution treatment. However, the sheets with fully or partially recrystallized structure may have lower strength properties and fracture toughness.

The combination of lengthwise and transverse rolling can provide the most favourable deformation texture pattern, thus reducing the degree of mechanical anisotropy.

The use during the cold rolling of intermediate heat treatment providing the regulated heterogenization of structure owing to the excessive phase precipitation hampers the deformation localization with the formation of shear bands. This results in lowering mechanical anisotropy (Tabl.2).

Table 2. Tensile properties of 1424 sheets 1,6 mm thick versus the intermediate heat treatment (after air quenching from 480^{O}C and three-stage aging)

Intermediate heat treatment	Structure	Direction	UTS, MPa	YS, MPa	Elongation, %
Quenching	Homogeneous solid solution	L	455	330	7
		LT	485	340	16
		45^{O}	390	270	27
Annealing	Heterogeneous	L	470	330	9
		LT	480	335	14
		45^{O}	430	315	16

The weldable and corrosion–resistant 1424 alloy sheets satisfy the following requirements: UTS ≥ 430 MPa, YS ≥ 280-300 MPa, $\delta \geq$ 7-10%, fracture toughness $K_{C0} \geq 85 MPa\sqrt{m}$, low-cycle fatigue life ≥150 kcycle (at σ_{max}=157 MPa and K_t=2,6).

References

1. J.N.Fridlyander, N.I.Kolobnev, O.E.Grushko, V.G.Davydov. Advanced Weldable Damage Tolerant AlMgLi Alloy for Aircraft Application. Conference Proceedings of The 5-th International Conference on Aluminium Alloys, Grenoble, France, 1996, V.4, 249-254

2. Mc Darmaid D.S. Effect of Thermal Exposure at 70 ^{O}C on the Performance of Damage Tolerant Al-Li Alloys Sheet. Technical report DRA/SMC/WP952008, DRA, Farnborough, 1995

3. V.N.Anan'ev, L.B.Ber, V.G.Davydov, V.I.Elagin, A.I.Orozov. Structural Aspects of Non-Stability of Properties of Al-Li Alloys in Condition of Prolonged Low-Temperature Heatings. Nonferrous Metals, №7, 1997, 59-63

4. J.N.Fridlyander, K.V.Chuistov, A.L.Beresina, N.I.Kolobnev. Alumimium-Lithium Alloys (Structure and Properties), Kiev, Ukraina, Naukova Dumka, 1992, 192