AMAG ADVANCED AA6061 ALLOY FOR AEROSPACE APPLICATIONS

Previous investigations [1-4] showed for the alloy AA6061 that the artificial aging response is adversely affected by natural aging at room temperature. A suitable pre-aging procedure at elevated temperatures immediately after solution heat treatment is effective in reducing the detrimental effects of natural aging on the artificial aging kinetics. The temper T4* produced hereby shows an increased aging response and after artificial aging to temper T6* exhibits a much higher level of mechanical properties.

In the present work the effects of pre-aging treatment are shown for alloy AA6061 in artificially aged temper T6* in comparison to sheet material manufactured without this additional heat treatment cycle after solution annealing. Both materials were characterized according to testing requirements typical of applications in the aircraft industry.
All investigated materials were produced from the same melt with a chemical composition within the tolerance limits of AA6061.

Results

The significantly higher strength of pre-aged 6061-T6* compared to conventional 6061-T6 is a result of the pre-aging treatment performed directly after solution heat treatment which has to be applied within a limited time interval after quenching [2, 3]. Both ultimate tensile strength and yield strength of the pre-aged 6061-T6* clearly exceed the A-and B-value basis listed in the MMPDS-04 Handbook [5] for AA6061-T6 sheet material, so that the A- and B-values could be increased for future aircraft applications when this enhanced pre-aged 6061 material is applied (see Figure 1).

Fatigue crack growth

The results of the dynamic tests are shown in Figure 2. Both AA6061 heat treatment variations generally show a satisfying crack growth rate, fulfilling also the requirements which apply to the most common skin quality alloy in the aircraft business AA2024-T3. In addition to the higher strength level of the pre-aged 6061-T6* alloy, also the fatigue crack growth rate is lower and therefore better than that of the conventional 6061-T6.

The results of the fracture toughness test are listed in Table I. The higher strength pre-aged 6061-T6* shows both for K_C and K_{app} higher values compared to conventional 6061-T6, but is slightly below the alloy AA2024-T3.

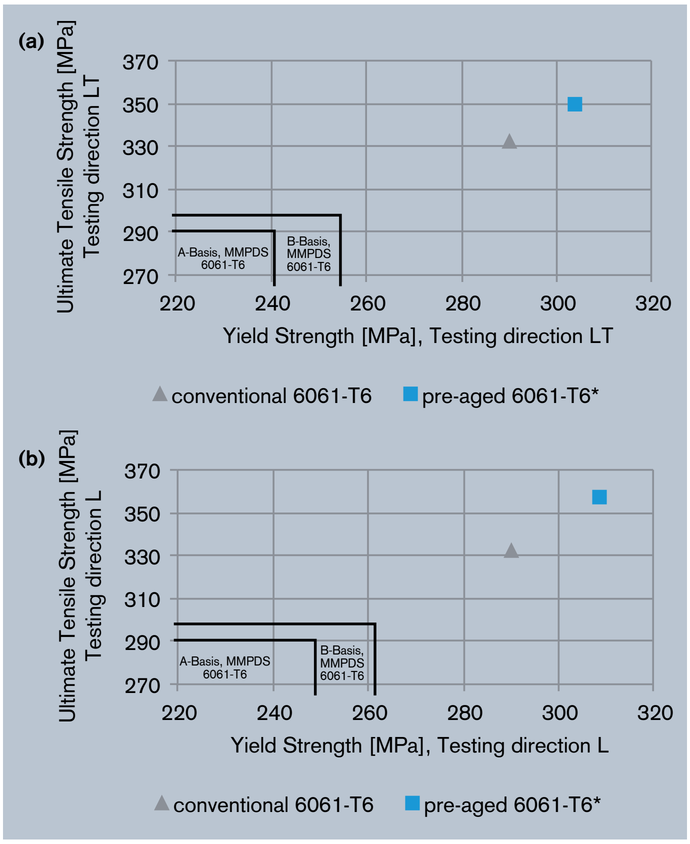


Figure 1: Mechanical properties of conventional 6061-T6 and pre-aged 6061-T6* compared to A- and B-values listed in MMPDS-04 [5], tested in direction (a) LT and (b) L
A-Basis: At least 99 % of the population of values is expected to equal or exceed the A-basis mechanical property allowable with a confidence of 95 %
B-Basis: At least 90 % of the population of values is expected to equal or exceed the B-basis mechanical property allowable with a confidence of 95 %

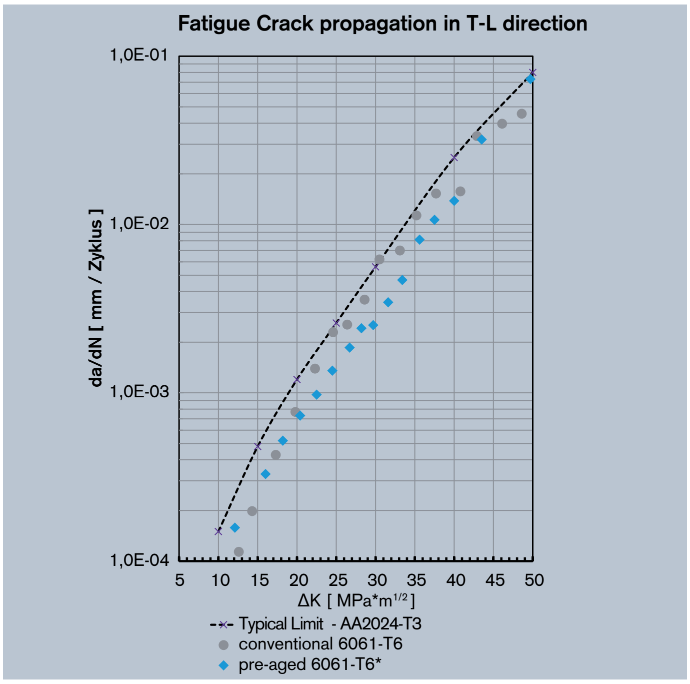


Figure 2: Fatigue crack propagation plot of conventional 6061-T6 and pre-aged 6061-T6*, compared to the typical limit curve for the most common aircraft skin quality alloy AA2024-T3, testing direction T-L (test according to ASTM E647 with a 160 mm wide center-notch sample and a stress ratio R = 0.1)

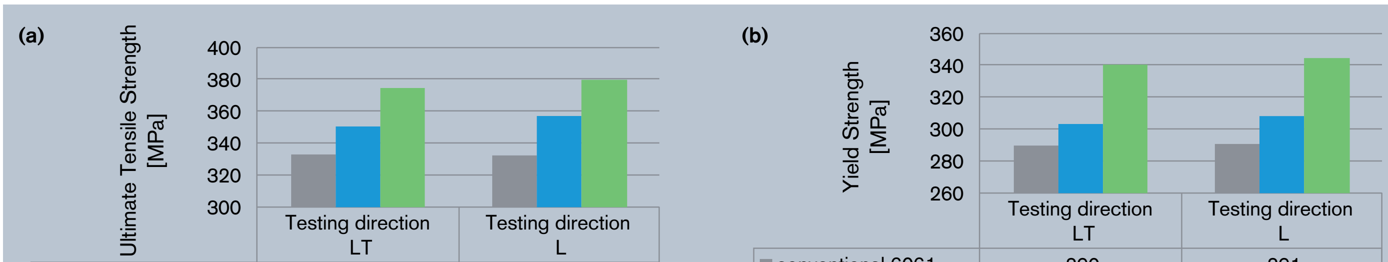
		6061-T6 conventional	6061-T6* pre-aged	AA2024-T3 typical
K_C	[MPa $m^{1/2}$]	134	138	156
K_{app}	[MPa $m^{1/2}$]	84	85	99

Table 1: Plane-stress fracture toughness Kc and apparent fracture toughness Kapp of conventional 6061-T6 and preaged 6061-T6* compared to typical values of AA2024-T3

Discussion

The increased mechanical properties in peak aged temper T6* go along with enhanced fracture toughness values as well as with a lower fatigue crack propagation rate, but without any negative influence on corrosion resistance [1]. It is assumed that the co-clusters formed during pre-aging exceed the criticallly stable size and, therefore, act as nuclei for ß``-precipitates resulting in an increased number density of this hardening phase in the microstructure [1, 4].

With AMAG Advanced AA6061-T6* even a further increase in mechanical properties can be attained with optimized thermo mechanical treatment after solution heat treatment (see Figure 3).
AMAG Advanced AA6061-T6*,with optimized chemical properties, furthermore offers a density reduction of 3.2 % in comparison to the aerospace standard alloy AA2024-T3 (see Figure 4). At a value of 2.69 kg/dm³, the density of AMAG Advanced AA6061-T6* is on a level comparable with 3rd generation of aluminium lithium alloys (e.g. AA2198).



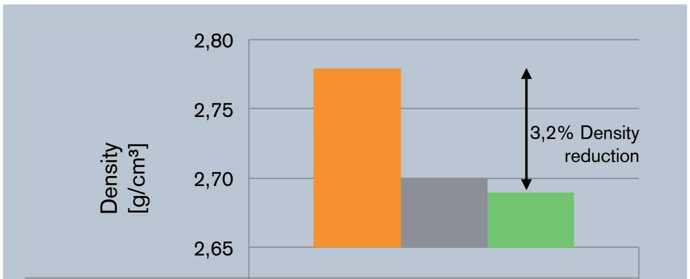
(a)

	Testing direction LT	Testing direction L
conventional 6061	333	332
pre-aged 6061	350	357
Expected, Advanced AA6061	370 – 390	370 – 390

(b)

	Testing direction LT	Testing direction L
conventional 6061	290	291
pre-aged 6061	304	308
Expected, Advanced AA6061	330 – 355	330 – 355

Figure 3: (a) Ultimate Tensile Strength and (b) Yield Strength of conventional 6061-T6 and pre-aged 6061-T6* compared to "Expected, Advanced AA6061-T6*", tested in direction LT and L The mentioned "expected" values of advanced AA6061 are based on laboratory investigations and have not yet been verified on industrial scale



AA2024	2,78
conventional AA6061	2,70
Advanced AA6061	2,69

Figure 4: Density of aerospace standard alloy AA2024-T3 in comparison to AA6061 and AMAG Advanced AA6061

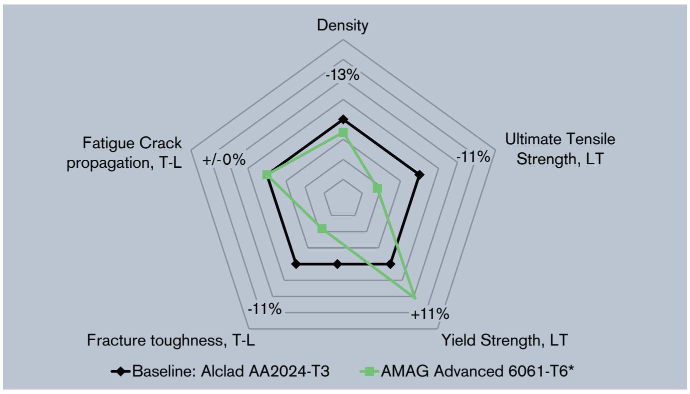


Figure 5: Summarized comparison of typical properties of Alclad 2024-T3 with AMAG Advanced 6061-T6*

Customer Benefits

AMAG Advanced AA6061-T6* has been optimized for high static strength making its mechanical properties comparable with various high strength 2xxx-series aluminium alloys, but offering superior corrosion resistance. Therefore, there is no need for a clad version which deteriorates the attainable mechanical properties. AMAG Advanced AA6061-T6* attains a level of mechanical properties which make it even comparable to Alclad 2024-T3 (see Figure 5).
The advanced AA6061-T6* sheet material just presented can be produced in series by AMAG in thicknesses of up to 6,35 mm (0.250 inch) thanks to additional heat-treatment equipment already integrated in the existing production line. It offers a density level as low as some AlLi-alloys but certainly at a lower price and it can be recycled with conventional technologies in place around the world.

Literature:

[1] J. Berneder, R. Prillhofer, P. Schulz, C. Melzer: "Characterization of pre-aged AA6061-T6 sheet material for aerospace applications", 13th International Conference on Aluminium Alloys (ICAA13), TMS (The Minerals, Metals & Materials Society), pp. 1797-1802, 2012 [2] C. Zelger, J. Schnitzlbaumer, R. Prillhofer, J. Enser, C. Melzer: „Optimized Heat treatment sequences for AA6061", Supplemental Proceedings, Volume 1, Materials Processing and Properties, TMS (The Minerals, Metals & Materials Society), 2010 [3] C. Zelger, P. Oberhauser, C. Melzer, P. Schulz: „Advanced 6xxx alloys for electronic applications", Proceedings of EMC 2009, pp. 1419-1425, 2009 [4] J. Berneder, R. Prillhofer, J. Enser, P. Schulz and C. Melzer: Study of the artificial aging kinetics of different AA6013-T4 heat treatment conditions, Supplemental Proceedings: Volume 2: Materials Fabrication, Properties, Characterization and Modeling, TMS (The Minerals, Metals & Materials Society), pp 321-328, 2011 [5] MMPDS-04: Metallic Materials Properties Development and Standardization (MMPDS), Battelle Memorial Institute, 2004