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Influence of annealing duration on properties of AlLiCuMg thin-walled extruded shapes

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I. INTRODUCTION

Annealing at higher temperatures of lithium containing aluminium alloys is accompanied by lithium depletion of the surface layer. In consequence, the change of the chemical composition in this layer leads to a change of material properties. The layer thickness depends on annealing temperature and annealing duration. Lithium depletion of the surface layer was investigated in the framework of a model experiment aimed to evaluate the effect of heat treatment parameters on the properties of thin-walled extruded shapes.

II. EXPERIMENTAL

An experiment was carried out to investigate the influence of annealing duration on mechanical and fatigue properties. Aluminium-lithium alloy Al_{2.6}Li_{1.9}Cu_{0.9}Mg_{0.1}Zr L-shape extrusions of dimensions 44x25x2 mm were used as experimental material. The material was solution-heat-treated at 530°C for 20 minutes and for 10 hours; annealing in salt bath and in air was performed. In order to assess the effect of small plastic deformations on properties after annealing the material was plastically deformed by stretching of rate 0 and 5 percent. After a two stage artificial ageing (150°C/4 h. + 170°C/18 h.) tensile tests, hardness HB 2.5/62.5 measurements, resistometrical measurements on the specimen surface and fatigue tests were performed. Fatigue loading with $R = 0$, $\sigma_{max} = 130$ MPa and 190 MPa and $K_t = 2.6$ and 1.1 resp., was used. The intensity of lithium depletion at different depth under the surface was determined by measuring microhardness HV 0.05 on polished metallographic specimens, representing a cross section of extruded shapes, at different distances from the extrusions surface.

III. RESULTS

Plots of microhardness values vs distance from specimen surface for materials annealed for 10 hours in salt bath and in air with zero plastic deformation are given on Fig. 1. The Li-depleted layer was 400 μm thick, the microhardness immediately at the surface was twice lower in comparison with the microhardness in material volume. The microhardness curves of specimens annealed in salt and in air were similar thus the effect on depletion intensity of both annealing media compared is the same. Plots of microhardness values vs distance from specimen surface for materials annealed in air for 20 min. without any subsequent plastic deformation and resp. plastically deformed (5%) are given on Fig. 2. For both cases the Li-depleted layer thickness was only 50 μm , the microhardness immediately at the surface represented again 50% of the value in the unaffected material.

The results of tensile tests, HB hardness measurements, fatigue tests and resistometrical measurements are summarized in Tab. 1. Values of strength R_m , yield stress $R_{p0.2}$, hardness HB 2.5/62.5 and electrical conductivity as a function of annealing and deformation parameters are plotted on Fig. 3 and 4. Fatigue curves as a function of heat treatment parameters are given on Fig. 5. The lithium depletion of the surface zone resulted in a degradation of mechanical properties of 8 to 10% for the specimens annealed for 10 hours with respect to the values for specimens annealed for 20 min. The yield stress degradation was more marked than the strength degradation. The hardness decrease and the electrical conductivity increase were also a consequence of the lithium depletion of the surface layer. From the experimental results the effect of the annealing medium on mechanical properties is not evident, on the contrary the effect of the deformation preceding the artificial ageing is significant.

Fatigue tests showed that the lithium depletion of the surface layer does not influence the fatigue behaviour of the material after a long-termed solution-heat-treatment at 530°C. The effect of lithium depletion was not proved by fatigue test on specimens with a central hole ($K_t=2.6$) for all variants. However, the results of the the tests on specimens with stress

concentration factor $K_t=1.1$ showed a small decrease of the mean value of fatigue life. However, considering the data scatter, that decrease falls on the limit of demonstrability.

IV. CONCLUSIONS

Annealing for 10 hours resulted in the formation of a depleted layer 400 μm thick, whereas the depleted layer thickness of samples annealed for 20 min. was less than 100 μm . The depleted layer thickness is not influenced by the annealing medium - it was almost the same for both media used. The experimental results for 10 hours annealing duration showed a decrease in strength and hardness, the decrease in elongation was not significant. Thus, the observed changes in properties result from the surface layers lithium depletion which leads to a decrease in strengthening phases amount. For $K_t = 2.6$ annealing duration did not influence fatigue properties, for $K_t = 1.1$ a weak decrease in mean fatigue life for samples annealed for 10 hours was observed. Mechanical and fatigue properties were affected the most markedly by the small plastic deformation preceding artificial ageing.

Tab. 1 Mechanical and fatigue properties and conductivity of heat treated extruded shapes

medium	salt bath				air			
duration [min.]	20	600	20	600	20	600	20	600
deformation [%]	0	0	5	5	0	0	5	5
R_m [MPa]	460	424	495	453	453	418	-	479
$R_{p0.2}$ [MPa]	356	323	433	396	370	330	-	425
A_H [%]	5.1	5.0	4.4	3.8	4.7	4.4	-	3.8
HB [1]	117	89	121	99	114	98	128	114
cond. [MSm^{-1}]	11.2	11.9	11.2	11.9	11.3	11.8	11.2	11.5
$N_{0.10g.10^{-3}}[1]$ $\sigma_{\max}=130\text{MPa}$	118	110	195	196	122	114	194	187
$N_{0.10g.10^{-3}}[1]$ $\sigma_{\max}=190\text{MPa}$	-	-	-	-	578	433	-	-

Fig. 1 - Microhardness curve as a function of the distance from extrusion surface - effect of different annealing medium on microhardness of the surface layer - specimens treated at 530°C for 10 hours, 0% stretching.

Fig. 2 - Microhardness curve as a function of the distance from extrusion surface - effect of deformation level on microhardness of the surface layer - specimens treated at 530°C for 20 min. in air.

a) Bar graph of strength for the different treatment variants

b) Bar graph of yield stress for the different treatment variants

Fig. 3 - Effect of heat treatment characteristics on:
a) Strength R_m ; b) yield stress $R_{p0.2}$.

a) Bar graph of hardness for the different treatment variants

b) Bar graph of conductivity for the different treatment variants

Fig. 4 - Effect of heat treatment characteristics on:
a) hardness HB; b) electrical conductivity.

Fig. 5 - Effect of heat treatment and stretching parameters on fatigue life.
 $\sigma_{max} = 130 \text{ MPa}$, $K_t = 2.6$