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Effect of Mechanical Treatment on Intergranular Corrosion of 6064 Alloy Bars

Sláma P., Nacházel J.

ABSTRACT

Al-Mg-Si-type alloys (6xxx-series alloys) exhibit good mechanical properties, formability, weldability and good corrosion resistance in various environments. They often find use in automotive industry and other applications. Some alloys, however, particularly those with higher copper levels, show increased susceptibility to intergranular corrosion. Intergranular corrosion (IGC) is typically related to the formation of microgalvanic cells between cathodic, more noble phases and depleted (precipitate-free) zones along grain boundaries. It is encountered mainly in AlMgSi alloys containing Cu, where it is thought to be related to the formation Q - phase precipitates ($Al_4Mg_8Si_7Cu_2$) along grain boundaries.

The present paper describes the effects of mechanical working (pressing, drawing and straightening) and artificial ageing on intergranular corrosion in bar of the 6064A alloy.

Corrosion tests showed that with continuing ageing and overaging, deep IGC changes into pitting corrosion with a smaller depth of attack. However, the corrosion resistance of the bars is impaired by post-quench mechanical working (drawing and straightening).

Experiment

The chemical composition of the EN AW-6064A bars is shown in Table (in wt.%).

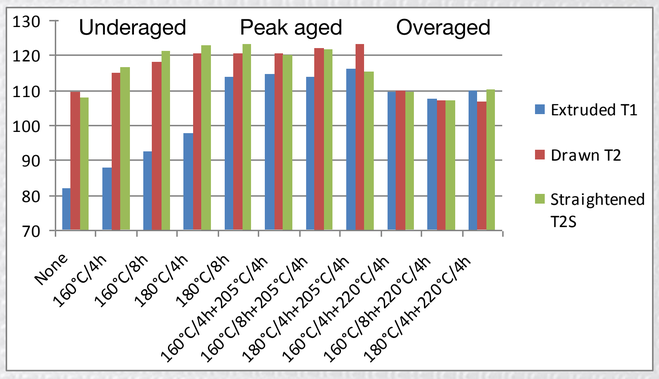
Si	Fe	Cu	Mn	Mg	Cr	Pb	Bi
0.60	0.23	0.27	0.04	1.03	0.05	0.28	0.49

The bars were made by an industrial hot extrusion process and right after extrusion the bars were water wave-cooled (temper T1). The quenched bars were then drawn to the final diameter of 15 mm (temper T2) and straightened (temper T2S). The final operation is artificial ageing (temper T8).

Effects of artificial aging (underaging, peak-aging, overaging) on the intergranular corrosion was investigated on the bars in the T1 and T2 temper.

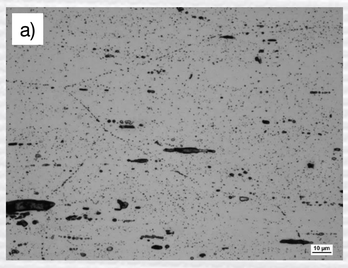
The resistance to intergranular corrosion was mapped using corrosion tests according to EN ISO 11846, method B

Hardness HV10 and depth of corrosion attack after artificial aging



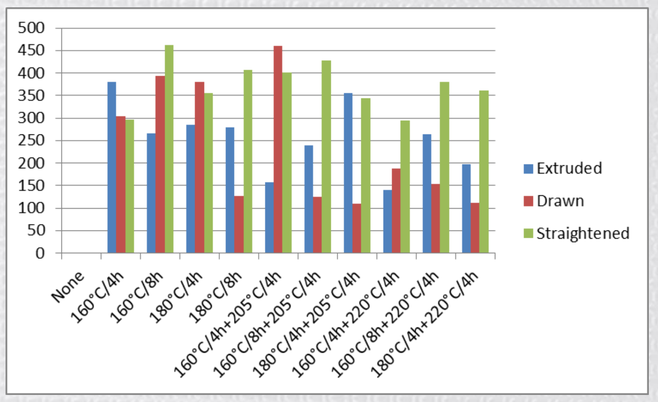
Hardness HV10 after artificial aging (one-stage and two-stage aging)

Microstructure and corrosion



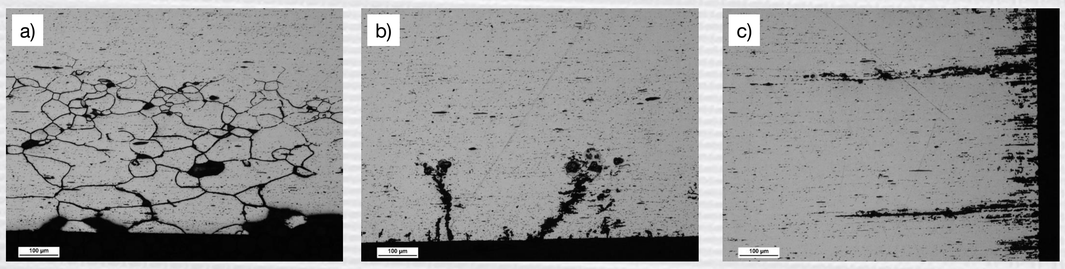
Microstructure of the bars in T8 temper

Large elongated particles consist of Bi or Bi+Pb. The small ones are alpha-$Al_{15}(Fe,Mn,Cu,Cr)_3Si_2$ particles. Other small particles are Mg_2Si particles. The small particles along grain boundaries are cathodic particles Q-phase ($Al_4Mg_8Si_7Cu_2$).

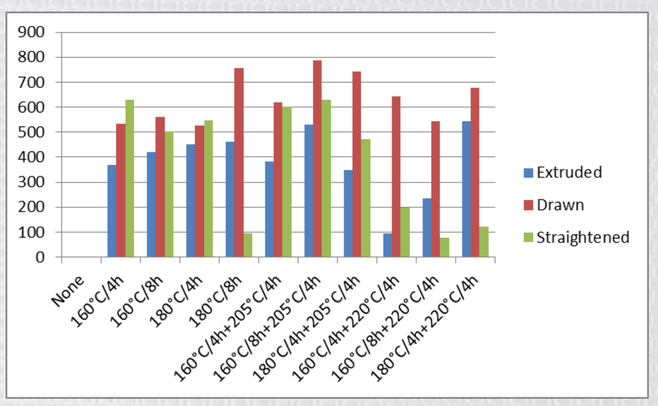


The depth of corrosion attack on the surface of the bar in μm

Corrosion attack of surface and cross-sections of bars after straightening



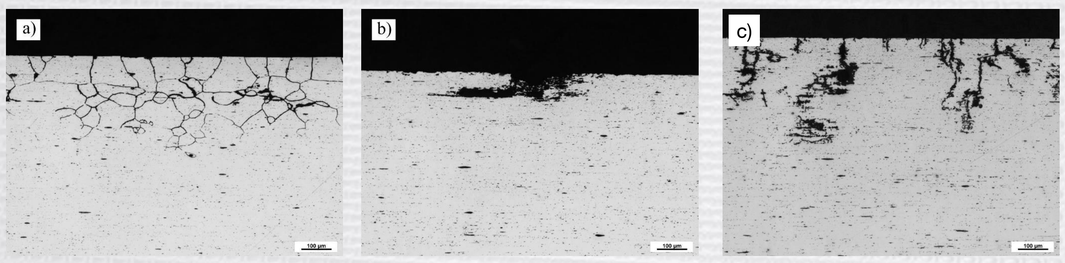
Surface – temper T2 | Surface – temper T8 | Cross-section – temper T8



The depth of corrosion attack on the cross-section of the bar in μm

Corrosion tests after experimental heat treatment (artificial ageing)

Surface - three types of corrosion



IGC – underaged condition from T1 and T2 temper

Pitting corrosion – peak aged and overaged condition from T1 and T2 temper

Transgranular corrosion – peak aged and overaged condition from T2S temper (after straightening)

Cross-section - the typical depth of corrosion is in aged condition

Temper T1 extruded + aging 160°C/4h+205°C/4h

Temper T2 drawn + aging 180°C/4h+205°C/4h

Temper T2S straightened + overaging 160°C/4h+220°C/4h

CONCLUSION

The bar surface exhibited three types of corrosion:

- IGC in underaged specimens: typically extensive corrosion with a depth of more than 300 μm.
- Pitting corrosion in more aged and overaged extruded/drawn bars, where the corrosion depth was approximately 100 μm.
- Transgranular pitting corrosion in more aged and overaged bars which had undergone final straightening. Here, the corrosion depth was larger and exceeded 300 μm.

With more intensive ageing and overageing (temperature, time), IGC changed into pitting corrosion in extruded/drawn bars. There was an adverse impact of the post-drawing straightening operation on the resistance to surface corrosion in the bars, evidenced by deep transgranular pitting corrosion.

In most cases, the transverse cross-sections exhibited very deep pitting corrosion with depths up to 800 μm which followed the bands of coarse cathodic phases. Exceptions were found in severely overaged bars (extruded or extruded and straightened) which showed sporadic pitting corrosion with depths of approximately 100 μm.

E-mail: peter.slama@comtesfht.cz / **www.comtesfht.cz**