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Mechanical properties degradation of (Al-Cu-Li) 2198 alloy due to corrosion exposure

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Abstract

The present work investigates the corrosion resistance of the innovative Al-Cu-Li (2198) aluminum alloy; a comparison against Al-Cu (2024) alloy is attempted. Tensile specimens were pre-corroded for different exposure times to exfoliation corrosion solution and immediately afterwards they were tested in tension. For small exposure times (< 12 h) small pits could be found on the corroded surfaces; pitting was also noticed at the small side surfaces (thickness) of the tensile specimens. Corrosion exposure seems not to essentially decrease the yield stress of AA2198 even for high exposure times, while this was not the case for AA2024. After heavy corrosion exposure (>12 h), AA2024 lost almost 30% of its initial ultimate tensile strength, while for AA2198 the respective value was only 11%. Al-Cu-Li alloy shows superior corrosion resistance in terms of maintaining higher percentages of tensile ductility; AA2198 exhibited higher remaining elongation at fracture values due to corrosion degradation for all investigated exposure times.

Keywords: alloy 2024; alloy 2198; tension; artificial ageing; exfoliation corrosion; ductility

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1. Introduction

The main driving force in aircraft structural design and aerospace material development is to reduce weight. Due to their high stiffness-to-weight and strength-to-weight ratios, aluminum alloys have been the dominant aircraft materials for many decades. In order to compete the decreasing tendency of Al usage in aero structures (in contrary to composite materials), aluminum alloy producers are making a huge effort in developing lighter and better weldable alloys. Li is added to Al-Cu alloys from the series 2xxx in a lower proportion than the Cu addition. They offer lower density than conventional aluminum alloys and direct weight reduction of about 5 %. The improved property balance i.e. corrosion resistance, fatigue crack growth rate, strength and toughness, allows further weight reduction up to 20% through adapted design, and reduction of aircraft maintenance costs. In order for the Al-Cu-Li alloy to replace the conventional one in aircraft structures, it has to be definitely proven that its mechanical behaviour, damage tolerance capabilities and corrosion resistance are at least equal or superior to its predecessor. Nevertheless, the literature about the mechanical behavior of the advanced Al-Cu-Li alloy seems to be rather limited. For example, Chen et al. (2011) performed tests on two different heat treated AA2198 (namely T351 and T851) and investigated their plastic and fracture behavior. Steglich et al. (2010a) and (2010b) investigated experimentally and analytically the anisotropic deformation of AA2198-T8 occurring during mechanical loading with and without the presence of artificial notches. Alexopoulos et al. (2013) have studied the fatigue mechanical properties of the advanced alloy and confirmed its superiority against its predecessor AA2024 in high-cycle fatigue and endurance limit regimes, especially when considering the specific mechanical properties of these alloys. Investigations on the corrosion resistance of AA2198 are even more limited.

In this direction at attempt is described in the present work to report experimental evidence regarding the corrosion potential of this alloy and directly compare the results against the respective one for the well-established AA2024. This work will focus on the comparison of the two alloys along with their resistance to corrosion, in terms of maintaining their tensile mechanical properties when pre-corroded for different exposure times.

2. Materials and experimental procedure

The materials used for the present investigation were AA2198 and AA2024 wrought aluminum alloys that were received in sheet form with nominal thicknesses of 3.2 mm. The weight percentage chemical composition of the 2198 alloy is <0.08 % Si, <0.01 % Fe, 2.9-3.5 % Cu, <0.5 % Mn, 0.25-0.8 % Mg, 0.8-1.1 % Li, 0.35 % Zn, 0.04-0.18 % Zr, 0.1-0.5 % Ag. Tensile specimens were machined along the longitudinal (L) direction of the material according to the ASTM E8 specification. Prior to corrosive solution exposure, all surfaces of the specimens were cleaned with alcohol according to ASTM G1 specification.

Table 1 shows the exposure corrosion times and the number of tensile specimens used in the present experimental protocol. Tensile specimens were exposed for different hours to the laboratory exfoliation corrosion environment (hereafter called EXCO solution) according to the ASTM G34 specification. The corrosive solution consisted of the following chemicals diluted in 1 l distilled water; sodium chloride (4.0M NaCl), potassium nitrate (0.5 KNO_3) and nitric acid (0.1 M HNO_3). Further details can be found in the respective specification. After the corrosion exposure the corroded specimens were immediately cleaned according to ASTM G34 and then they were subjected to tensile testing.

Table 1. Investigated exfoliation corrosion exposure times and number of tensile specimens.

	Different exposure times to EXCO solution										Total
	0 h	0.5 h	1 h	2 h	4 h	6 h	8 h	12 h	24 h	48 h	
# of spec. AA2024-T3	5	3	3	3	3	-	3	3	3	-	26
# of spec. AA2198-T3	5	-	-	3	-	3	-	3	3	3	20