# SIMULATION OF THE CORROSION-INDUCED CRACKS WITH EQUIVALENT ARTIFICIAL SURFACE NOTCHES

**Nikolaos D. ALEXOPOULOS[1], Christina Margarita CHARALAMPIDOU[1], Paraskevas PAPANIKOS[2], Stavros K. KOURKOULIS[3]**

[1] Department of Financial Engineering, School of Engineering, University of the Aegean, 41 Kountouriotou str., 82132 Chios, Greece, e-mail: nalexop@aegean.gr

[2] Department of Product and Systems Design Engineering, School of Engineering, University of the Aegean, 1 Konstantinoupoleos str, Ermoupoli, 84100 Syros, Greece

[3] Laboratory for Testing and Materials, Department of Mechanics, National Technical University of Athens, 5 Heroes Polytechnion Str., 15773 Athens, Greece

## 1. Introduction

Corrosion of aluminium alloys is among the greatest problems in maintenance and repair of aircraft structures. Interaction of corrosion with other forms of damage, e.g. fatigue cracks, can result in loss of the structural integrity of aircrafts components mainly due to accelerated crack propagation [1] The major damage mechanism on the corroded surface is the formation of pits that act as stress concentrators and assist cracking formation and therefore affects the integrity of aircraft structures [2-4]. Aluminium alloys such as 2024, which are widely used in the aircraft industry due to their improved mechanical properties, are susceptible to corrosion attack due to their microstructure [5-6]. To face the corrosion-induced structural degradation issue, available data usually refer to accelerated laboratory tests including weight loss measurements, metallographic analysis, measurements of the depth of corrosion attack etc. The most common accelerated corrosion laboratory test used for the aeronautical aluminium alloys 2xxx and 7xxx is the exfoliation corrosion (EXCO) test, according to ASTM G34 specification. Except from atmospheric corrosion, it is not foreseen in any specification/standard to perform mechanical tests on pre-corroded materials and the rate of the corrosion degradation rate is not correlated to the residual mechanical properties. However, for the AA2024-T3, various mechanical tests had been carried out to assess the influence of corrosion damage on the structural integrity of the material. Tensile and fatigue tests in pre-corroded material resulted to a moderate degradation of the material's mechanical strength properties, e.g. yield stress and ultimate tensile strength, along with a significant reduction of the tensile ductility [7-9]. According to Alexopoulos et al. [10] the cross-sectional area of AA2024 specimens that is unaffected by the corrosion-induced micro-cracks, also referred as 'effective thickness', decreases exponentially with increasing corrosion exposure time due to the crack propagation mechanism. The reduction of the specimens load carrying cross section as well as the notch effects caused by pitting formation are responsible for the moderate reduction of the tensile strength properties. In the present work, simulation of the real corrosion-induced degradation of the mechanical properties due to micro-cracks as well as hydrogen embrittlement and correlation with the equivalent degradation by artificially-induced surface notches was investigated. A finite element model was developed to calculate the residual mechanical properties of the simulated technological problem with artificial notches.

## 2. Materials and methodology

Material used was a wrought aluminium alloy 2024-T3 received in sheet form of 3.2 mm nominal thickness. The chemical composition of 2024 alloy is 4.35% Cu, 1.50% Mg, 0.64% Mn, 0.50% Fe, 0.50% Si, 0.10% Cr, 0.25% Zn, 0.15% Ti and Al rem. Tensile specimens were machined from the sheets longitudinal to the rolling direction and according to ASTM E8 specification. The geometrical dimensions were 12.5 mm x 3.2 mm at the reduced cross section with total length of 150 mm. Artificial surface notches of different depths, e.g. 0.15, 0.30 and 0.50 mm in each surface, were machined in the specimens large (top) surfaces in order to simulate the gradually increasing corrosion attack.

Specimens geometry was modeled with the aid of the ANSYS program. Modeling was conducted along the thickness of the specimens (width in real specimens). Due to symmetry in both axes, only ¼ of the specimen's width was modeled. Hence, the geometrical dimensions of the modeled area were 1.60 mm width (half of the thickness) x 12.5 mm length, since the length of the extensometer in the tensile tests was 25 mm. Two dimensional elasto-plastic finite element analyses were conducted to calculate the behavior of the specimen with artificial notches. Since the width of the specimen is large compared to its thickness, plane strain conditions were assumed. The stress-strain curve of AA2024-T3 was used as input to the model.

## 3. Results

Fig.1 shows the calculated tensile curve for 0.15 mm notch depth and is directly compared against the experimental results of the tensile tests. A good correlation between the experimental results and the calculated from the FEM is evident. Additionally, typical sketches of the development of plastic zone at different loading levels are depicted. In the case (a) the specimen is loaded to the plastic region up to 2 % nominal strain while levels up to 5 % and 6 % are depicted in (b) and (c), respectively. The developed plastic zone tends to increase in size and morphology is changed such as in high plastic strain region. This is the typical geometry of the ductile fracture in 45° to the loading axis. Fracture is assumed to occur at the loading level at which the plastic zone is stretched to the whole width of the specimen of the modeled area, as can be seen in case (d).

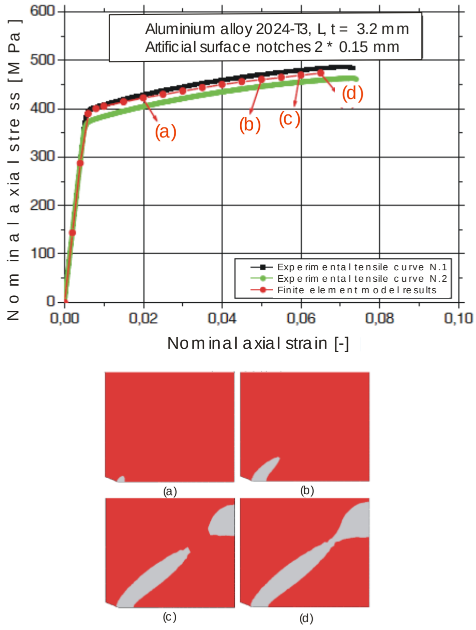

**Fig. 1.** Experimental tensile curves of AA2024-T3 pre-corroded specimens (upper) compared against the FEM calculated curve and plastic zone development at different tensile loading levels (lower).

## 4. Conclusions

Artificial surface notches of different depths were machined on the tensile specimens surfaces for the simulation of corrosion-induced mechanical properties degradation. The corrosion exposure time was empirically correlated to the total notch depths regarding the remaining tensile ductility. A finite element model was developed to simulate the real corrosion-induced mechanical properties degradation of the artificially notched specimens. A good correlation between the calculated results from the model and the experimental results was noticed.

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