A new specimen to evaluate susceptibility of aerospace alloys to crack deviation in integral structures

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The current aircraft structures tend to increase the proportion of integral structure parts. One main advantage is the cost, through a reduction of the assembly complexity. The fatigue behaviour of integral structures is improved due to a reduction in potential initiation sites at joints or rivets, and the stiffness is also considered better. The design of new parts requires, however, an analysis of the damage tolerance behaviour [1]. The present study focuses on the fatigue crack propagation of such structures.

Complex parts are commonly machined in aluminium thick plates. Depending on the position, if a crack appears in the structure, the loading might be among others in L-T, T-L or L-S with respect to the material rolling direction. Several studies underline that standard aerospace alloys can show some crack deviation due to stiffened geometries themselves through T-stresses [2], or simply due to mixed-mode loads. Some other studies demonstrate that the deviation can occur in unstiffened L-S specimens for standard alloys [3], [4]. The combination of these factors (geometry, alloy) determines the final crack path behaviour in integral structures. A specimen evaluating the deviation susceptibility, combining those contributions, is still lacking.

The first test results presented in this study are obtained on L-S CT specimens, considered as the most standard method to evaluate the crack deviation sensitivity. The CT geometry is shown sufficient to discriminate behaviour variations between three positions through-thickness in a 7xxx plate.
The second test results are obtained using a new asymmetric four-stiffener specimen (WEND) geometry in the L-S configuration (Figure 1). Two symmetric stiffeners are present on each side. The stress state at the crack tip is extracted from Finite Element simulations, to allow future comparisons with real integral structures. The simulations are done under the assumption of a straight path in a linear elastic material. Experimentally, in order to demonstrate the advantage of the WEND specimen, a 7xxx and a 2xxx aerospace alloy are characterized. The same alloys are characterized using a CT specimen. Whereas the alloys behave almost identically in the CT, they differentiate very clearly with the WEND.

The WEND specimen is proposed as a lab-scale test closer to real structures than CT test. In its first use, it allows to compare an alloy behaviour with a target lifetime vs crack path. In its second on-going use, it enables the comparison with Finite Element Modelling for a better crack path and lifetime prediction.

Figure 1. WEND specimen in an alloy showing a straight path after completion of the fatigue test.

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