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New approach in metallic fatigue strength methods with enhanced consideration of size effect and stress gradient

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Points d'intérêt.

- Fatigue in large aircrafts
- Current airbus analytical method could be optimized for complex geometries
- Investigation on highly stress volume, critical distance and probabilistic approaches
- Encouraging results, but extra tests needed

1 Context

Metal fatigue cracking is a well-known phenomenon in large aircraft environment. It implies various type of design (splicing, stress raiser, lugs...) and materials. In the 90's Airbus has developed an analytic method to design its aircraft, with the objective to guaranty a minimal fatigue life. This method assesses the effect of the different parameters affecting fatigue life, of which the scale effect.

In the current approach, a knockdown factor estimated through a 1D geometric model using Equation (1) covers the scale effect and the stress gradient. [1]

$$E = \left(\frac{a}{r}\right)^{0.08} \quad (1)$$

Where a is a constant, and r the notch radius (in millimeter).

This approach has proven to be adequate for most of aircraft designs to be analysed. Nevertheless, this approach could be optimised for more complex structures. In addition, 3D finite element models could provide more quantities of interest such as stress gradients and spatial stress fields.

Therefore, Airbus is investigating an approach to assess quantitatively the size effect and the stress gradient from detailed 3D finite element models.

Eventually, the selected approach could be integrated in future Airbus fatigue assessment methods.

1 Study

Several approaches have been investigated by Airbus and ONERA: the highly stressed volume, critical distance (point, line, surface, or volumic methods)[2], and probabilistic [3].

These approaches have been applied on available coupon test results for an 7175-T7351 aluminum alloy. These coupons included round notch specimens with elastic stress concentration (K_t) of 1.0, 1.7, and 3.3.

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The probabilistic approach was not able to predict properly the behavior, mainly due to the input coupon test results that was not adequate to calibrate the method.

The critical distance approach gives encouraging results. However, none of the 3 methods covers the full fatigue cycles ranging from 10^4 cycles to 10^6 cycles for the coupon test available.

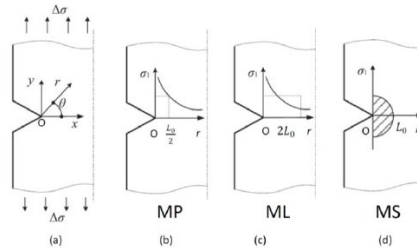


Figure 1. notched specimen with uniaxial loading(a), and schematic representation of the critical distance approach at point (b), line (c), and surface (c) (Luo et al., 2019).

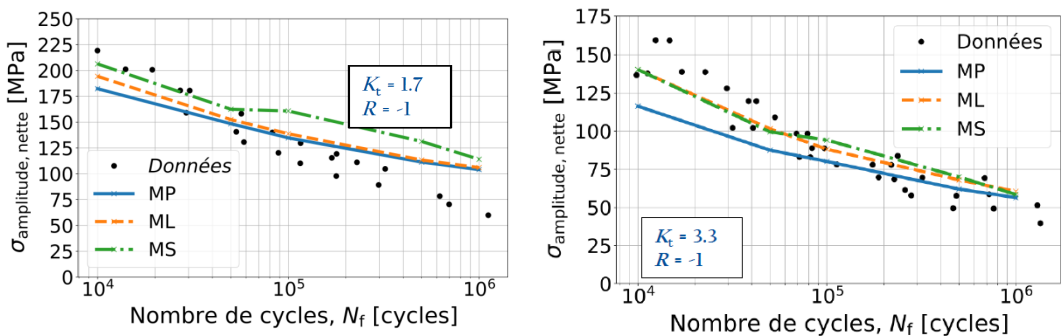


Figure 2. Critical distance approach result for $K_t=1.7$ and $K_t=3.3$ coupons, $R= -1$

2 Conclusion

This study will continue in the following years with new testing to correctly implement the probabilistic approach, and with cyclic hardening caraterisation to hopefully improve the fatigue life prediction of notched structure.

Références

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