

A design and validation process for structural bonded joints exposed to harsh service conditions

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Introduction

Adhesive bonding is now a well-established joining procedure, used extensively in high performance industries, such as those operating in the automotive and the aerospace sectors. However, its use in critical applications is still hindered by the lack of confidence in joint performance under harsh conditions. To allow for consistent joint use, it is fundamental to provide assurances in three major topics, which are damage tolerance, durability and damage detection (Figure 1). In this work, damage tolerance and durability are discussed.

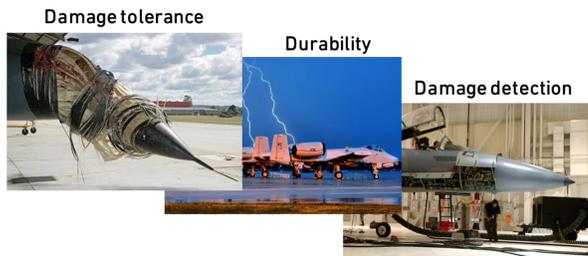


Figure 1 –Key research topics on the durability of bonded joints

Damage tolerance of bonded composites

Composites are often found in high performance applications, but bonding these materials is challenging, due to their low transverse strength. Adhesive layers, due to load misalignment, can generate large peel loads, which delaminate the composite in the through the thickness direction as the overlap increases (Figure 2).

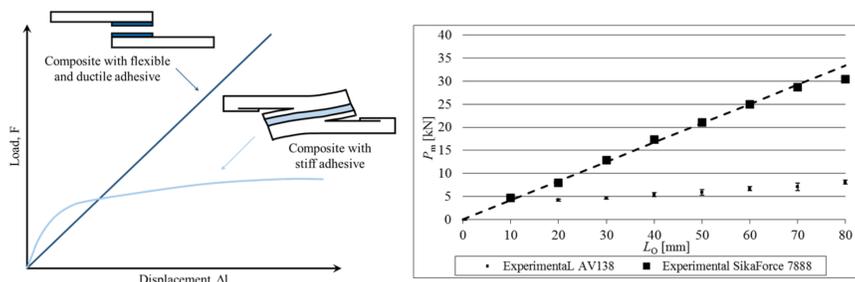


Figure 2 –Delamination of composite bonded joints as a function of the overlap length

New techniques have been devised to address this issue, mitigating the stress levels in the adhesive layer. One consists in the variation of the adhesive properties along the joint, using mixed or functionally graded adhesive layers, as shown in Figure 3.

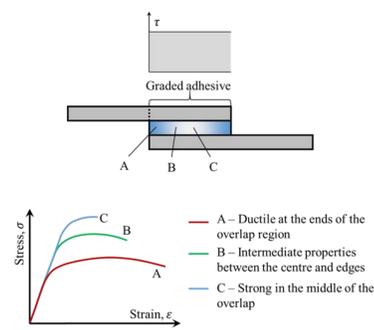


Figure 3 – Functionally graded joint concept [1]

Other techniques have been devised by our team at INEGI to control the stress levels in the adhesive layer, based on the concept of surface toughening. This concept (Figure 4) uses a global surface layer, with a tough matrix, which redistributes the stresses acting on the adherend, avoiding delamination.

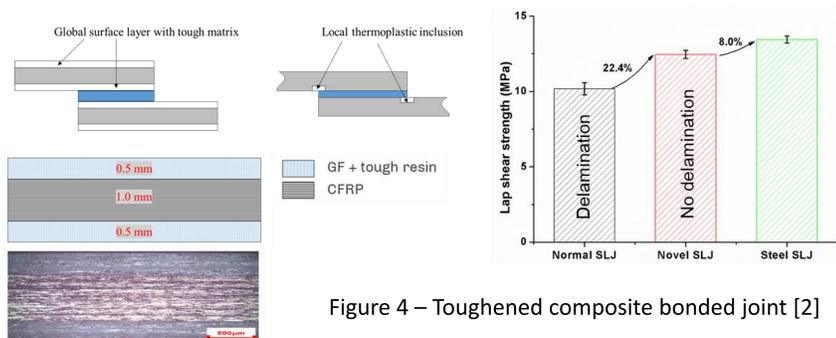


Figure 4 – Toughened composite bonded joint [2]

Durability

Moisture ageing and fatigue are the most challenging conditions faced by adhesive joints under service, leading to premature failure, as shown in Figure 5.

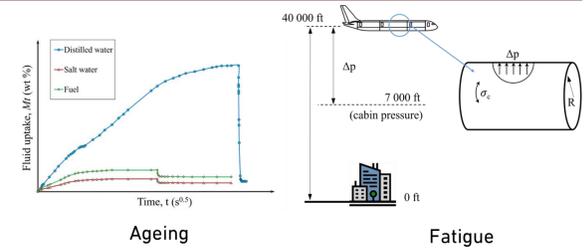


Figure 5 –Ageing and fatigue sources in bonded joints

Fatigue design of bonded joints can follow two different philosophies, either based on an S-N master curve or following the cohesive element degradation approach (Figure 6)

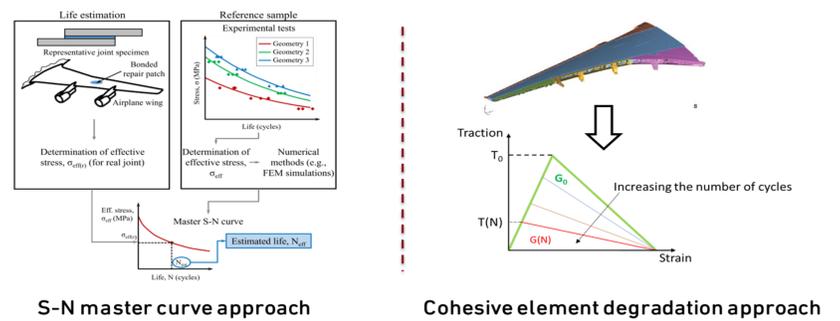


Figure 6 – Comparison of fatigue design approaches for bonded joints[3].

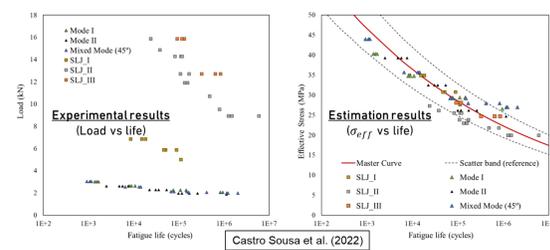


Figure 7 – Experimental and estimated fatigue life using the S-N master curve approach for bonded joints [3].

The numerical degradation of cohesive elements is a generally more powerful approach, allowing to introduce the effect of fatigue (Figure 8) but also of moisture (Figure 9). Triangular traction separation laws are adjusted cycle per cycle as function of the moisture content/ fatigue cycles.

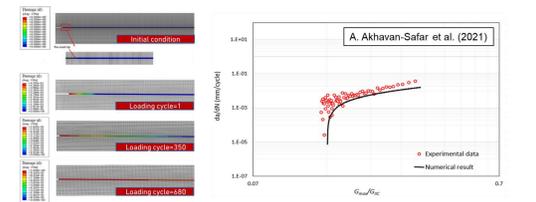


Figure 8 – Fatigue induced degradation of cohesive element properties [4]

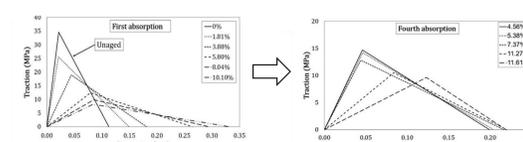


Figure 9 – Moisture induced degradation of cohesive laws

Conclusions

- New approaches have been developed to enhance the damage tolerance of bonded composite joints, using stress level control.
- Fatigue and moisture induced damage can be predicted using different approaches, based on fatigue life master curves or the degradation of material properties in finite elements.

References

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Acknowledgements

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