Fatigue behavior of environmentally aged dissimilar adhesive joints for the automotive industry

E. A. S. Marques (INEGI, Portugal), J. J. M. Machado, A. Q. Barbosa, L.F.M da Silva

Advanced Joining Processes Unit

Introduction

Lighter materials such as composites and aluminium alloys have been widely introduced in the automotive industry over the last decades. Joining such materials using adhesives allows automotive manufactures to obtain structures offering high mechanical strength with significant weight reduction [1]. Automotive structures undergo different hygrothermal conditions (water and temperature) during its life cycle and are subjected to repeated loads, being important to understand the joints fatigue behaviour under those circumstance [2,3]. The novelty of this work is the assessment of the behaviour of joints made using CFRP and aluminium substrates under different fatigue loads (60, 40 and 20%) and environmental states.

Experimental methodology

Unaged joints were kept in a container full of silica to after manufacturing;
Hygrothermally aged joints were immersed in deionized water for 2000 hours at 50 °C (inside a environmental chamber);
Dried joints were kept in container with silica at 50 °C (inside an environmental chamber).

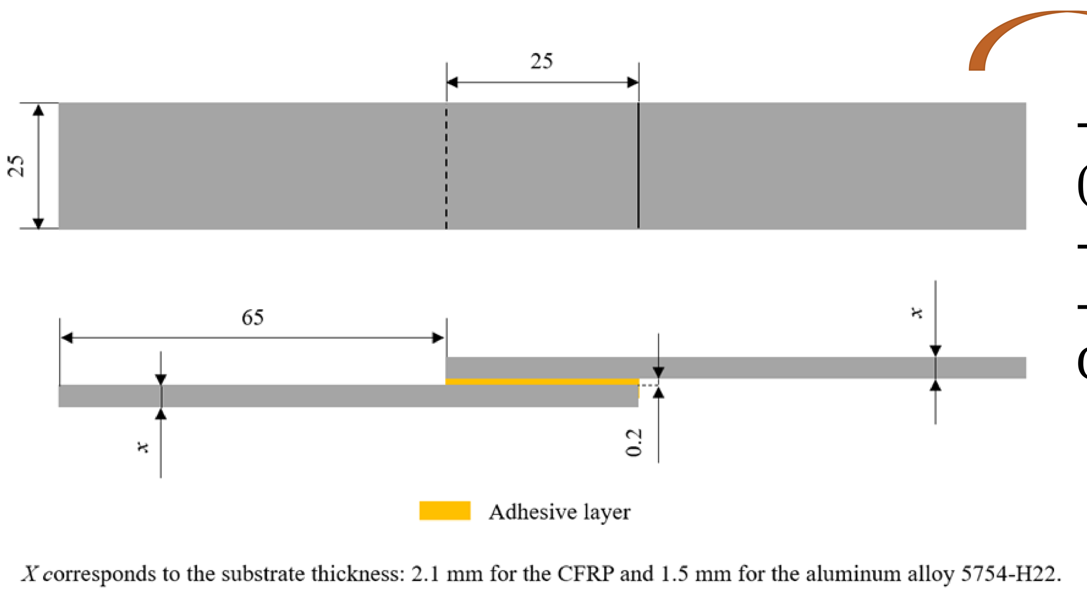

Figure 1 – Schematic representation of the SLJs used.

- CFRP - Unidirectional carbon/epoxy (SEAL® Texipreg HS 160 RM).
- Aluminium alloy – Al 5754-H22
- Crash resistant adhesive Nagase ChemteX XNR6852 E-3.

Single lap joint configurations:
Similar substrates (CFRP + CFRP)
Dissimilar substrates (CFRP + Al 5754-H22)

Discussion

Quasi-static tests, failure loads for dissimilar joints were almost identical. Such fact, associated to the similar failure surfaces and bending of the 5754-H22 aluminum, revealed that the highest possible joint strength was never achieved, limited by the occurrence of peel loads. For the case of joints with similar substrates there was a decrease of failure load when hygrothermally aged, being such value recovered after drying the joints after hygrothermal aging.

Joints with similar substrates, considering a total number of cycles to failure bellow 10000, it was possible to observe that joints dried and unaged could undergo higher stress 20 MPa than the joints hygrothermally aged 15 MPa. Also for a stress of 15 MPa, it was possible to observe that joints dried and unaged can achieve higher cycles than 100000 up to failure under fatigue, as for the case of the hygrothermally aged joints such value was under such barrier. The one million cycles target was achieved by the unaged (stress of 6MPa) and dried (stress of 3 MPa) joints. As for the hygrothermally aged joints, they failed prior to such value.

Joints made with dissimilar substrates can achieve higher number of cycles of fatigue up to failure in comparison with joints made with similar substrates, although, at much lower loads. Considering a stress of 8MPa, hygrothermally aged joints allowed for <10000 cycles to failure, as the dried after hygrothermal aging and unaged joints achieved 100000 cycles. Tests taken under 3MPa the behaviour of all joints was similar (although slightly inferior for hygrothermally aged joints).One million of cycles to failure were achieved for all joints conditions tested under 3 MPa.

Experimental results

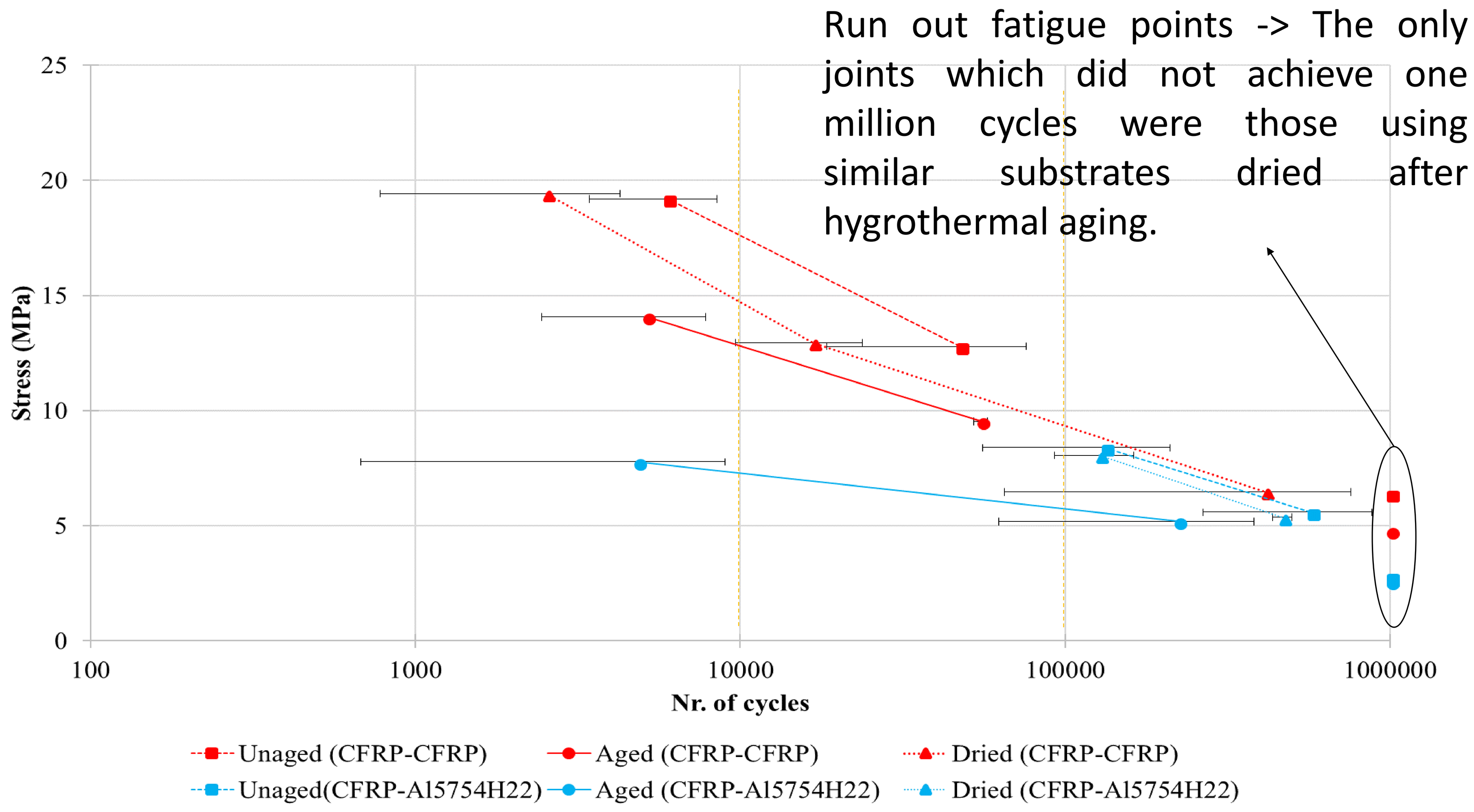

Figure 2 – *S-N* curves for fatigue tests performed using joints made with similar a dissimilar substrates under three distinct conditions: unaged, hygrothermally aged and dried after hygrothermal aging.

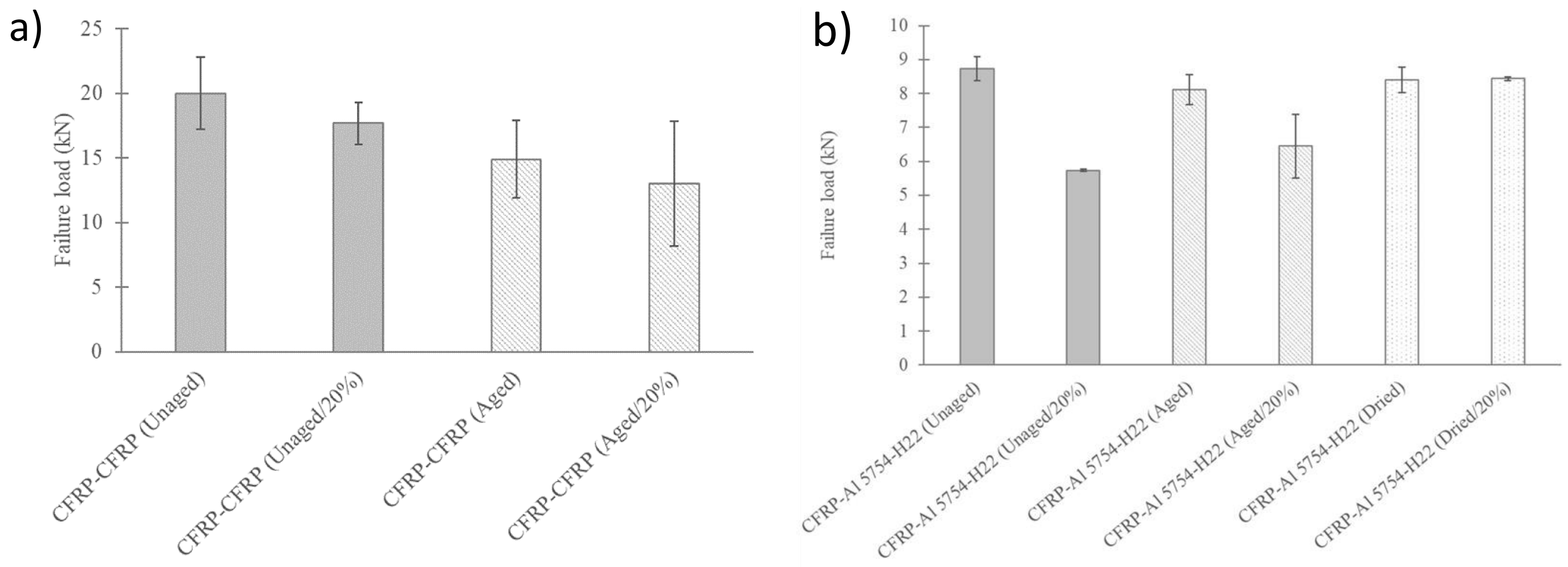

Figure 3 – Comparison in terms of failure load between joints tested at: unaged, hygrothermally aged, dried after hygrothermally aging conditions versus the remaining failure load of joints under the same conditions after achieving one million of cycles (20% of failure load) under fatigue. a) joints made with similar substrates (CFRP + CFRP) and b) dissimilar substrates (CFRP + Al 5754-H22).

Conclusions

The experimental results allowed to conclude that for both similar and dissimilar joint combinations, hygrothermally aged joints exhibited a decrease in the number of cycles to failure while, for both cases, a partial recovery in terms of number of cycles to failure was observed after drying the specimens. For low values of failure loads it was possible to achieve one million of cycles to failure for several conditions.

References

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