A comprehensive review exploring the improvement of fatigue life and strength in adhesively bonded composite joints

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Advanced Joining Processes Unit

Introduction

Adhesive bonding is widely seen as the most optimal method for joining composite materials, bringing significant benefits over mechanical joining, such as lower weight and reduced stress concentrations. Adhesively bonded composite joints find extensive applications where cyclic fatigue loading takes place, but this might ultimately lead to crack damage and safety issues. Consequently, it has become essential to study how these structures behave under fatigue loads.

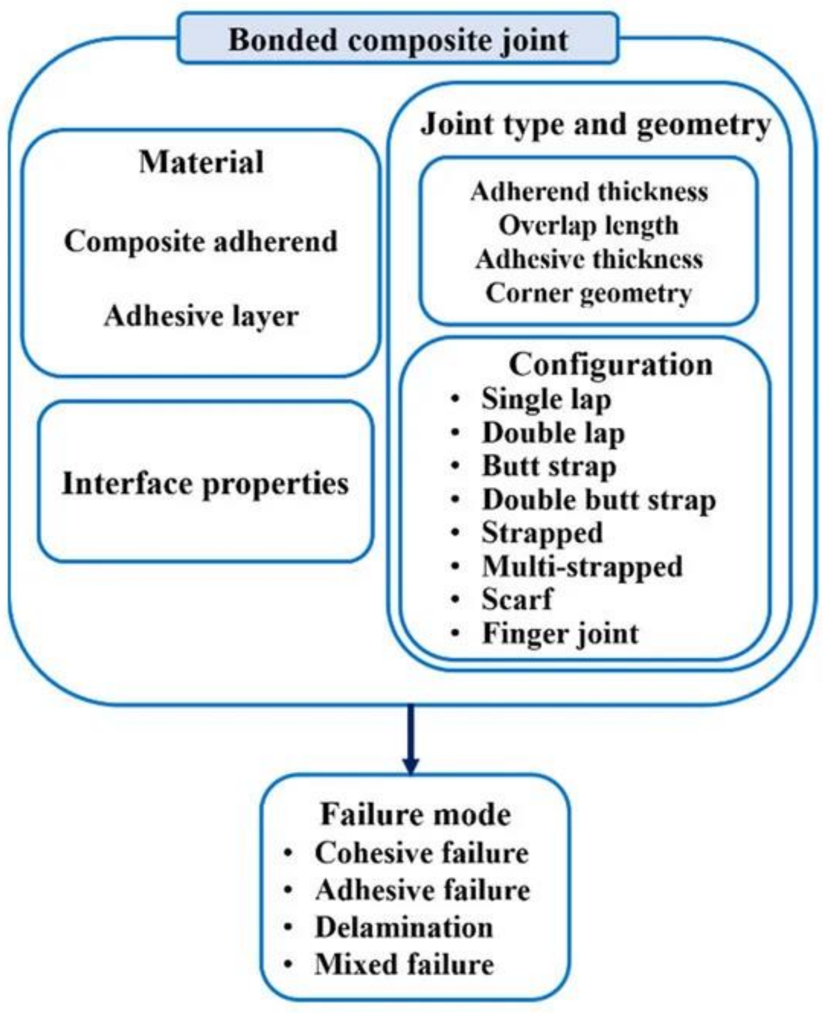

Figure 1 – Effective parameters on fatigue life.

Joint configuration and geometry

Scarf joints exhibited a higher fatigue life than butt joints of equal CFRP adherends thickness, regardless of the scarf angle. As the thickness of the CFRP adherends in the butt joint increases, the fatigue strength is reduced due to the volume effect of CFRP, and the dominant failure mode shifts from primarily delamination to cohesive failure.

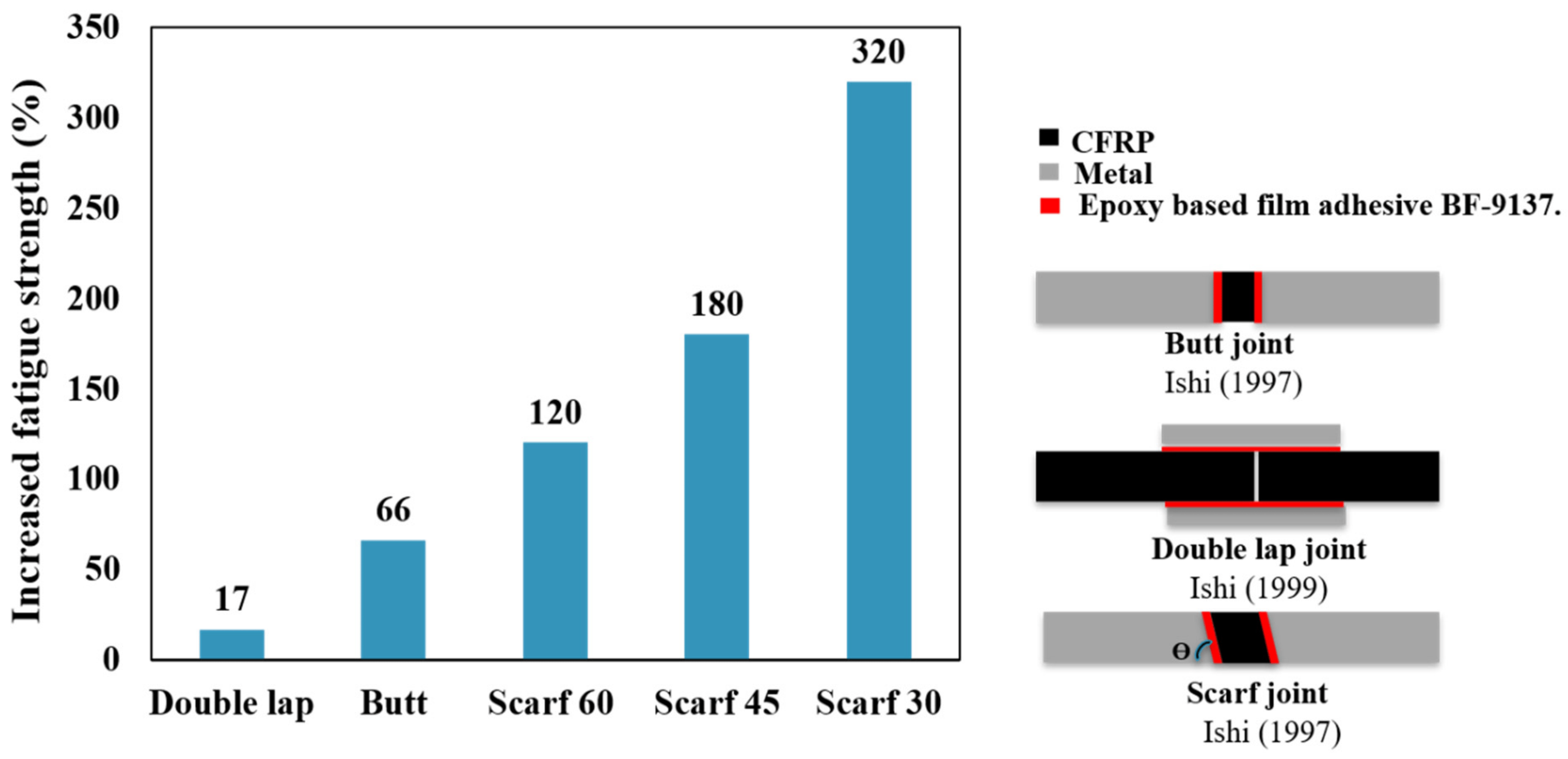

Figure 2 – Fatigue strength (corresponding to 1 × 106 cycle) improvement for different configurations in comparison to the SLJ [1,2].

The reduction in peel stresses and stress concentrations at the joint ends are key factors contributing to improvements in fatigue strength of different configurations.

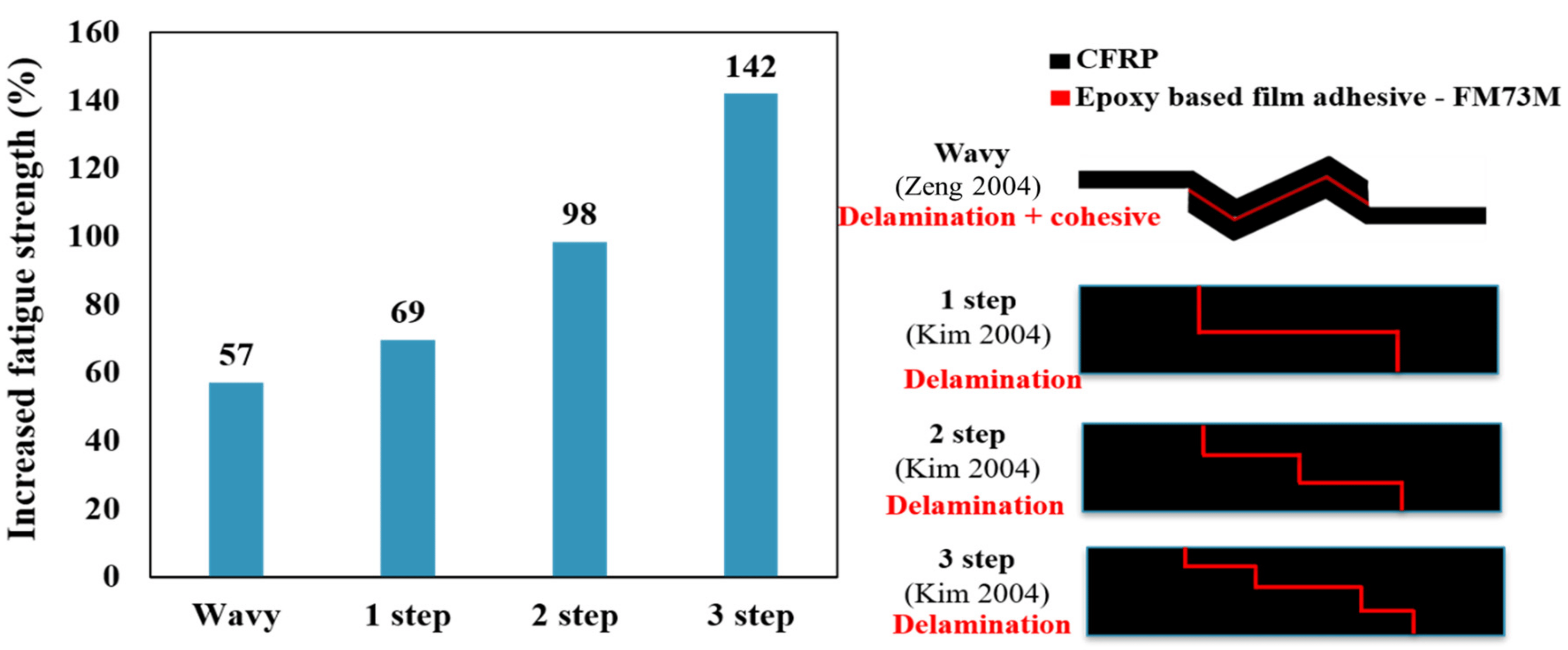

Figure 3 – Fatigue strength improvement for different configurations compared to conventional SLJs [3,4].

Overlap length

The fatigue strength is not directly and linearly proportional to the overlap length. Increasing the overlap might increase fatigue strength in some cases, but not always. Single-lap joints show longer fatigue life with longer overlaps in cohesive/adhesive failure, while adherend failure joints show varied or opposite trends with overlap length.

Fillet and adhesive thickness

Changing the joint-end geometry with a spew fillet spreads the load transfer over a larger area, resulting in a more uniform shear stress distribution. Fatigue strength of adhesively bonded composite joints has been enhanced by incorporating a spew fillet at the overlap ends.

As the adhesive layer becomes thicker, the anticipated lifespan of the joint diminishes.

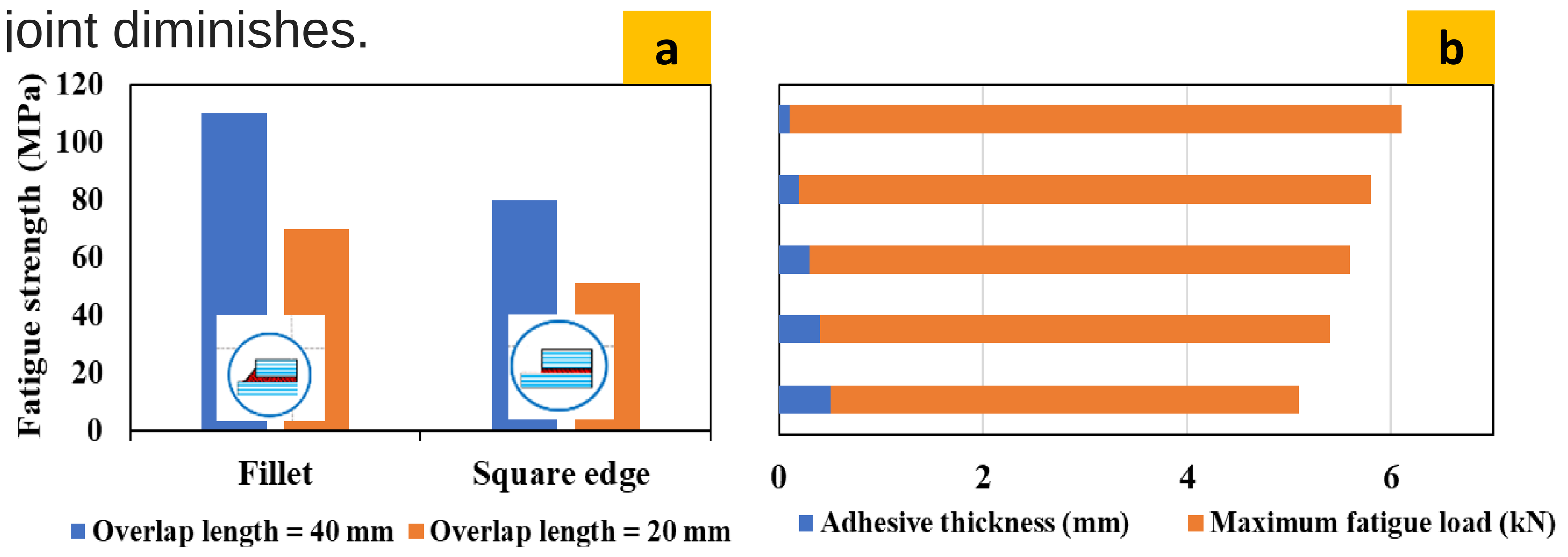

Figure 4 – a) corner fillet and b) adhesive thickness effect on fatigue strength [5,6].

Adherend modification

The proportion of 0° layers has a direct impact on the increase in fatigue strength and influences the mode of failure. It can be explained by increasing the stiffness of joints with more 0° layers.

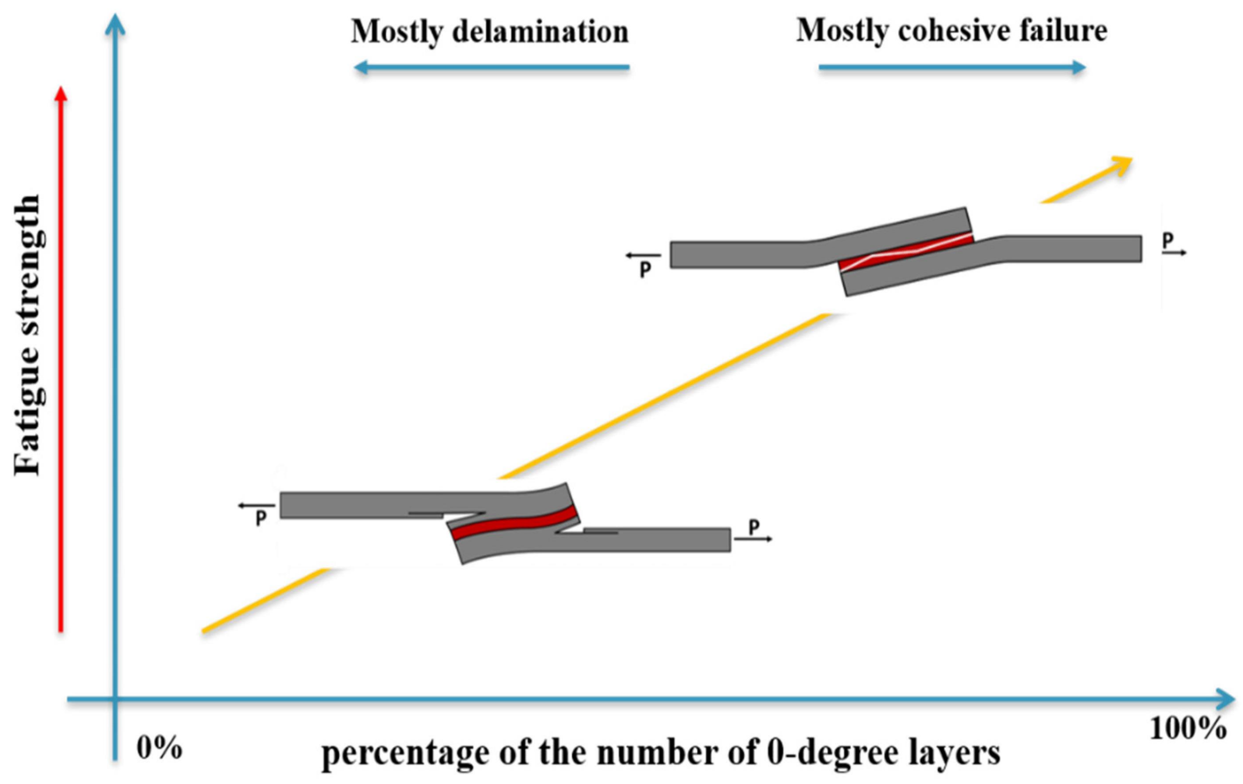

Figure 5 – Effect of proportion of 0-degree layer through the thickness of adherends.

Conclusions

- It has been shown that changing the geometry of joints can increase the fatigue strength.
- The primary factor that significantly influences joint strength is the configuration of the joints.
- Increasing the overlap length had a more significant impact on improving the fatigue strength of adhesively bonded composite joints compared to the use of corner fillets.
- the proportion of 0° layers directly affects the rise in fatigue strength and also alters the mode of failure by affecting the composite adherends' stiffness.

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