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FATIGUE PERFORMANCE OF REINFORCED SINGLE LAP JOINTS IN A CARBON FIBRE COMPOSITE

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1. Introduction

Carbon fibre-reinforced polymer (CFRP) laminates are used in aerospace due to their effective strength to weight ratio. Until today thin walled composite structures are joined by using a large number of fasteners. Secondary adhesive bonding of primary parts would considerably contribute to the weight and cost reduction but they cannot fulfil the airworthiness requirements up to now [1]. Using fasteners as crack stopping features is one way to achieve the certification [2]. This work investigates possible innovations for the bolted connection using inserted washers to reinforce the bolted area [3].

2. Materials and Methods

The reference sample and two types of innovative technologies for joining of CFRP laminates were evaluated. Two types of washers inserted into the carbon fibre fabric laminate during manufacturing were used for the innovative specimens - smooth washer and spiked 3D print washer. The specimens were single lap joints with one fastener. Two slabs of 20 and 13 plies were joint for each specimen. The joints were bonded by adhesive (REDUX FM300) and fastened by a fastener (ABS1707 B C2 V1 A).

The fatigue tests were performed on INOVA ZUZ 100 kN and Hydropuls Schenck 250 kN with maximum load of 8 600 N and coefficient of asymmetry R = 0.1. In selected intervals C-scan using a phased array probe was performed.

3. Results

The results of fatigue crack growth of a single lap joint with adhesive bonding and a fastener are shown in Fig. 1 and Fig. 2. Fatigue crack fronts during loading were marked based on single transducer ultrasonic probe. Typically the crack propagated first from the bottom edge and then from the upper. The C-scan revealed also crack initiation from the washer border. Fatigue crack growth curves were determined based on the ultrasonic detection. The reinforced series showed less final crack acceleration, and thus improved fatigue behaviour in comparison with the reference specimen and with the smooth washer.

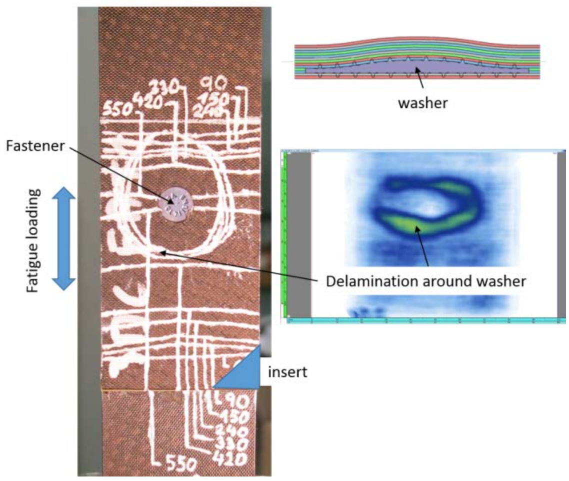

Fig. 1. Fatigue crack fronts during loading and a delamination initiation from the washers

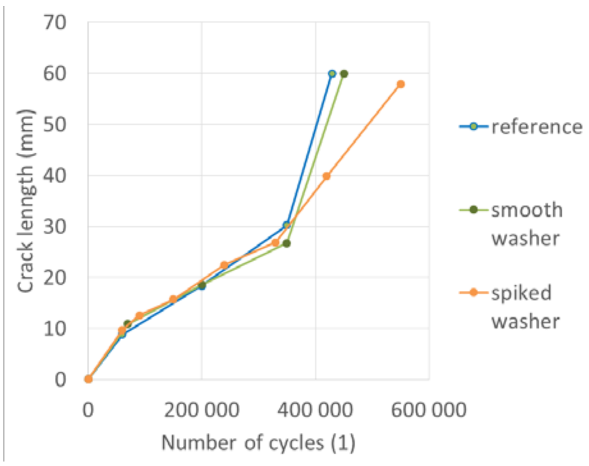

Fig. 2. Fatigue crack growth curves.

A macro photography of fracture surfaces revealed fibre and matrix dominated fracture which corresponded with crack growth and shearing direction. The mechanism of angled cracks is explained in Fig. 3. The cracks initiated at both free edges and then they were driven diagonally toward one of the bonded surface due to the shear forces that caused 45° major stress direction. The cracks propagated along the interfaces until they reached the bolt.

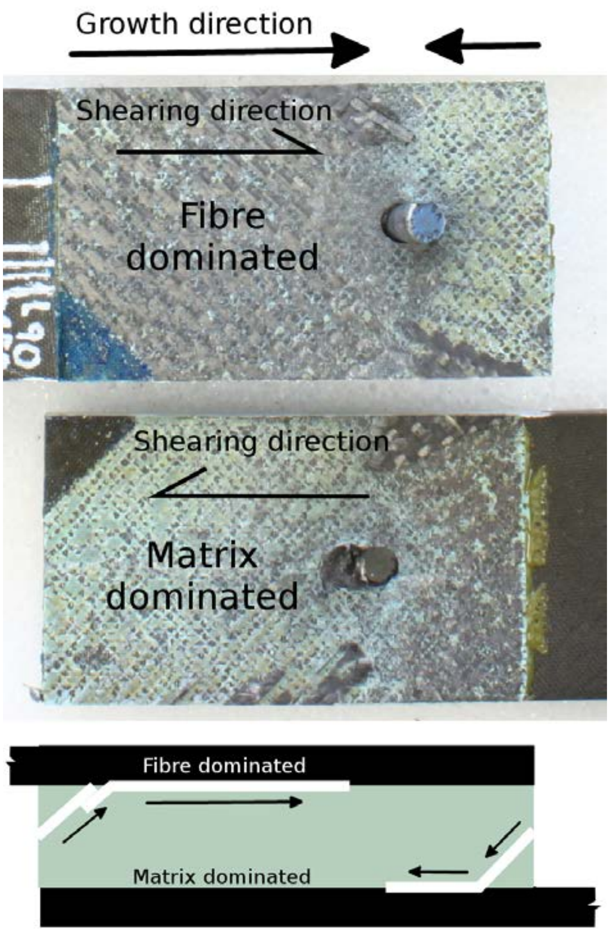

Fig. 3. Fatigue crack fracture surface with explained angled crack mechanism leading to fibre and matrix dominated fracture.

4. Conclusion

To conclude, the results of fatigue loading of single lap shear joints showed that the reinforcement influenced only the final stage of crack growth where it hindered the crack and increased the joint lifetime by 30%. The fatigue crack growth mechanism was explained. The crack stopping features have great potential to enable certification of adhesive joints for primary aerospace structures.

Acknowledgements

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