Effect of variable amplitude fatigue loading on intralaminar crack initiation and propagation in multidirectional gfrp laminate

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EFFECT OF VARIABLE AMPLITUDE FATIGUE LOADING ON INTRALAMINAR CRACK INITIATION AND PROPAGATION IN MULTIDIRECTIONAL GFRP LAMINATE

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ABSTRACT

Studies have shown that the fatigue life of multidirectional laminated fibre composites is reduced for variable amplitude (VA) block loading and for random load spectra compared to constant amplitude (CA) loading [1]. One of the hypotheses in the literature for this is a cycle mix effect that causes an additional increase in damage each time the load increases i.e. load amplitude or mean load. However, only a single study [2] has shown through experiments that additional intralaminar damages occur after load changes. In the current work, the underlying mechanisms resulting in change in fatigue life are studied [3]. The current work confirms the cycle mix effect, and more importantly identifies that the load changes from high to low loads are the most significant causes for the increased damage rate during VA fatigue loading.
The experimental campaign was conducted on a GFRP laminate with a $[+45, -45, 0_5]_S$ lay-up with a total nominal thickness of 2.2 mm, see Figure 1. Variable amplitude block loading with 1000 low load cycles (VA-L) followed by 50 high load cycles (VA-H) was applied in the tests. For reference, constant amplitude low loads (CA-L) and constant amplitude high load (CA-H) tests were also conducted. The length and location of the matrix cracks in the off-axis layers were tracked throughout the fatigue tests using an automated image processing algorithm [4]. From this the crack density evolution, crack density rates, as well as crack initiation and propagation of each individual intralaminar crack contributing to the total crack density are derived. The crack tracking algorithm used here is modified compared to the original formulation in [4] in order to increase the accuracy and precision making it possible to detect small changes in crack density rates when changing from one load block to another.

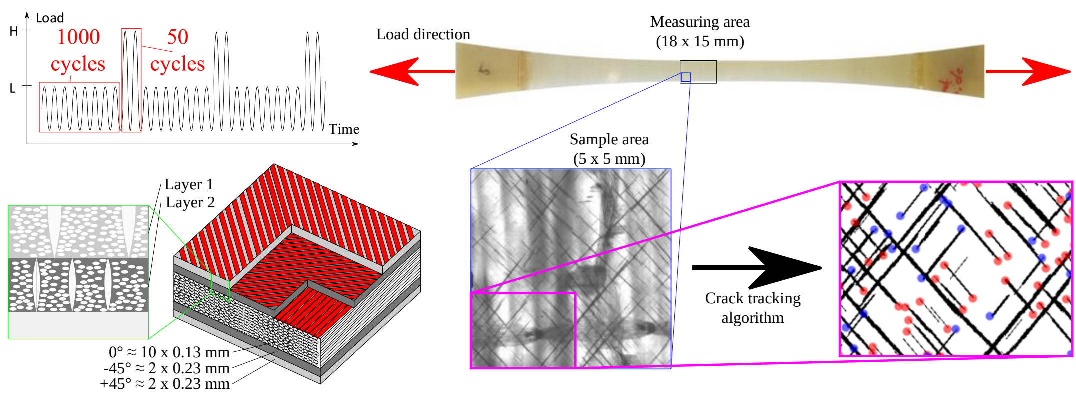

Figure 1 Variable and constant amplitude loading experiment on off-axis laminates with detailed tracking of the intralaminar cracks.

The measured crack density as a function of load cycles is presented in Figure 2. The results show a near step-change in crack density rate going from low load blocks VA-L to high load blocks VA-H. However, from high load blocks VA-H to low load blocks VA-L there is a clear gradual transition of the crack density rate from the level during the high load block VA-H to the level in the low load blocks VA-L which lasts for 200-300 cycles.

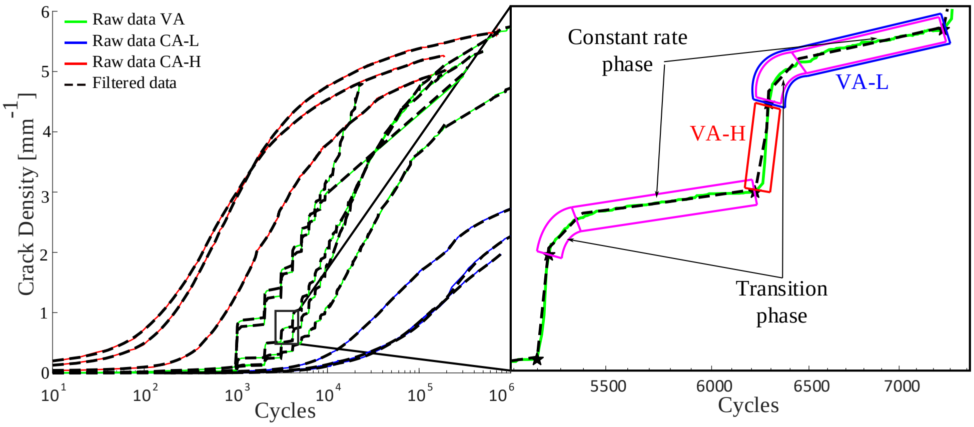

Figure 2 Crack density in VA load tests, showing change in rate when the load amplitude changes.

The crack density rates are for VA-L and VA-H presented in Figure 3. Throughout the test the crack density rates in VA-L and VA-H are both higher than the reference CA-L and CA-H, respectively. The crack density rate for the VA-L blocks is different from the CA-L tests in the way that they are apparently constant through the test, in contrast to the reference CA-L tests where the crack density rate decreases significantly through the test. This is valid for both the transition phase and the constant rate phase.

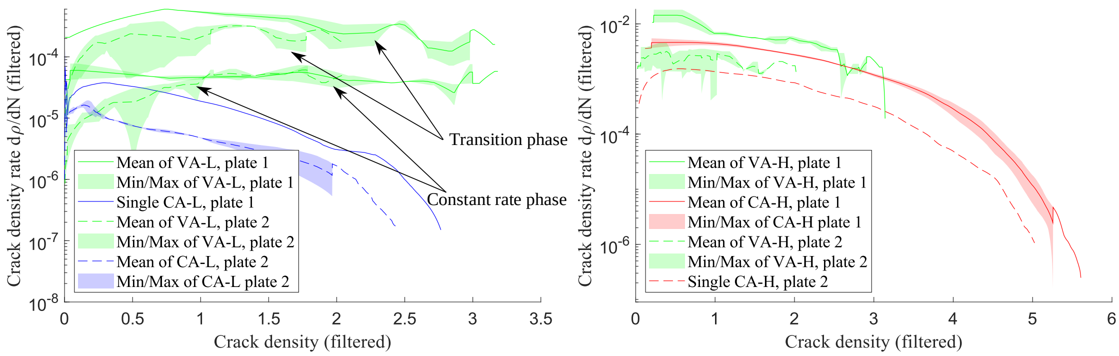

Figure 3 Crack density rate of low load VA-L and CA-L (left) and high load VA-H and CA-H (right). The VA-L loading data is split into the transition phase and the constant rate phase to highlight the significant difference.

In conclusion, the VA load blocks increase the damages caused by the high loads, and in particular the low loads. At CompTest these novel investigations will be presented in detail together with additional results regarding how the number of cracks, crack lengths, crack initiation, and the crack density transition phase depend on the loading spectrum.

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