Delay in Crack Initiation due to Carbon Nano- Particle Reinforcements

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ABSTRACT

Composite materials are used instead of metals in many weight-sensitive applications because of their superior performance embodied in their higher specific stiffnesses and strengths. They are now exclusively used in various primary load-bearing parts of aircraft and helicopters, for example. It has been observed [2] that with the addition of a secondary reinforcement in the form of Carbon nano particles (CNP), the strengths of fibre reinforced polymer composites increase. The current work deals with a comparison of the one-dimensional stiffness matrix of a tapered composite flex beam, with and without CNP reinforcements. The beam without the CNP reinforcement is shown to have lower strengths. As a result, it is demonstrated that the crack tends to initiate at a quicker rate when the beam is cyclically bent in time.

The full paper intends to qualify the delay in the onset of the crack due to the addition of the CNP to the composite beam. Modeling will be focussed around a matrix-rich region so that the presence of the CNP will enhance the strength of that region and hence a delay in the crack initiation is anticipated. The non-homogeneity of the doubly reinforced composite is handled analytically using the Mori-Tanaka method [1] of continuum micromechanics. Delamination in the beam occurs due to the failure of bonding between the layers. In general, here will be three stresses acting in between the layers along three Cartesian coordinates (x_1 along the length, x_2 along the width, x_3 along the thickness of the beam), namely: σ_{13}, σ_{23} and σ_{33}. σ_{13} is the shear stress acting along the length of the beam (direction of the fibre) while σ_{23} and σ_{33} are the stresses along the breadth and the thickness of the beam, respectively. σ_{23} & σ_{33} can be neglected in comparison to σ_{13} for cantilever beams which are dynamically loaded only with a transverse flexural load acting at the tip along x_3. Meanwhile the interlaminar shear strength, S_{13}^{0} (without CNP) will be calculated as a function of the number of cycles (S-N curve) for the region selected and will be compared to the updated stress, σ_{13}. Due to the cyclic application of the flexural load, at some point of time, σ_{13} will become higher than S_{13}^{0} . At that time, when $\sigma_{13} > S_{13}^{0}$, the beam undergoes fatigue failure and delamination starts to occur. In order to delay/avoid this, CNP will be introduced in the matrix-rich region and the enhanced interlaminar shear strength will be calculated as S_{13}^{n} (with CNP). Based on the Mori-Tanaka model, the interlaminar shear strength with CNP is predicted to be a function of the CNP reinforcement parameters, and demonstrated to be higher than the stiffness matrix without CNP, i.e., $S_{13}^{n} > S_{13}^{0}$, thus causing a delay in the initiation of delamination in the composite flex beam. In the full length paper, the calculation of S_{13}^{0}, modelling of the matrix-rich region and calculation of S_{13}^{n} will be presented.

REFERENCES

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[2] C. L. Tucker III, E. Liang, “Stiffness predictions for unidirectional short-fibre composites: Review and evaluation”, *Composites Science and Technology* **59**, 655-671 (1991).