Model of Structural Damage to Carbon Fibre Composites Due to Thermo-electric Effects of Lightning Strikes

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The impact of a lightning strike causes a short high electrical current burst through Carbon Fibre Composites (CFC). Due to the electrical properties of CFC the large current leads to a rapid heating of the surrounding impact area which degrades and damages the CFC. It is therefore necessary to study in detail the thermal response and possible degradation processes caused to CFC. The degradation takes place in two ways, firstly via direct mechanical fracture due to the thermal expansion of the CFC and secondly via thermo-chemical processes (phase change and pyrolysis) at high temperatures.

The main objective of this work is to construct a numerical model of the major physical processes involved, and to understand the correlation between the damage mechanisms and the damage witnessed in modern CFC. For this work we are only considering the thermo-chemical degradation of CFC. Bespoke numerical models have been constructed to predict the extent of the damage caused by the two thermo-chemical processes separately (e.g. a model for phase change and a model for pyrolysis).

The numerical model predictions have then been verified experimental by decoupling of the damage mechanisms, e.g. the real Joule heating from a lightning strike is replaced by a high power laser beam acting on composite surface. This was done to simplify the physical processes which occur when a sample is damaged. The experimentally damaged samples were then investigated using X-ray tomography to determine the physical extent of the damage.

The experimental results are then compared with the numerical predictions by considering the physical extent of the polymer removal. The extent of polymer removal predicted by the numerical model, solving for pyrolysis, gave a reasonable agreement with the damage seen in the experimental sample. Furthermore the numerical model predicts that the damage caused by polymer phase change has a minimal contribution to the overall extent of the damage.