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MODELLING DAMAGE PROGRESSION IN STIFFENED COMPOSITE PANELS UNDER IMPACT

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ABSTRACT

A critical safety issue for the design of primary aircraft structures is vulnerability and damage tolerance due to foreign object impacts from bird strike, hail, tyre rubber and metal fragments. New composite aircraft structures are particularly vulnerable to impact damage, due to the thin composite skins and the generally brittle behaviour of carbon fibre reinforced epoxy resins. Physical phenomena associated with impact damage and progressive collapse of composite structures are complex, and predictive models and simulation tools for design and analysis are being widely investigated. The paper uses meso-scale composites damage models [1], [2] in explicit FE codes to study damage progression in composite structures under impact. Key issues discussed in [3] are the development of models for composites in-ply damage and delamination failure, modelling bonded and riveted joints, materials laws for soft body impactors such as birds and tyre rubber, and the efficient implementation of the materials models into FE codes. Multi-scale modelling techniques are required because impact damage is localised and requires fine scale modelling of delamination and ply damage at the micromechanics level, whilst the structural length scales are much larger. Focus in the paper is the prediction of damage progression in stringer stiffened composite shells due to impact from metal objects and tyre rubber fragments, with gas gun test data on panel structures used to validate the impact damage models.

DLR has recently completed a set of gas gun impact tests on T-stringer stiffened CFRP panels, with steel, ice and rubber projectiles at impact velocities in the range 50 - 175 m/s. Impact damage was studied in HS film and by ultrasonic C-scanning impacted panels. The tests showed the critical influence of delamination failures in controlling local energy absorption and impact penetration. The main focus of the paper is on FE simulation of the observed damage and comparison of numerical results with test data. Materials parameters for the meso-scale damage models were obtained from DLR test programmes and used to determine ply damage parameters and delamination failure energies G_{IC} and $G_{IIC.}$ Numerical studies were carried out to model delamination tests which helped identify critical models parameters for the cohesive interface delamination

model. FE panel models were then developed based on stacked shells for the composite laminate with cohesive interfaces and parametrised such that fine scale meshes could be used in the contact regions with coarser meshes away from the impact. FE studies were made to predict impact damage for steel cube and steel bar impacts at velocities in the range 40 – 100 m/s, which represent the impact scenario of hard debris impact on the runway during start or landing. For impact between stringers there was a critical velocity at which penetration took place, which was well predicted by the model. For impact at the stringer position the projectiles rebounded but caused local delamination damage or stringer debonding over part of its length. This agreed well with HS film of the test and the measured size of the damaged region obtained by ultrasonics.

A second study was made of tyre rubber fragments impacting composite panels with bonded and riveted C-stiffeners. With such deformable projectiles skin penetration is not usually important and observed damage such as delamination or stiffener debonding may be away from the impact position due to wave effects. A study was made of the role of delamination in the damage progression as the impact velocity is increased and adjacent stiffeners become damaged. This emphasised the role of delamination in modelling soft body impact damage in composite structures, which requires fine scale meshes, and showed the need for multiscale strategies if impact damage is to be simulated in larger aircraft structures.

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