

# MODELLING AND TESTING OF HAIL IMPACT ON AIRCRAFT COMPOSITE LAMINATES

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## Abstract

Hail impact on composite structures during flight occurs at high velocities and is a serious concern as it may cause large internal delaminations not visible on the impacted surface. The present paper gives an overview of experiments and modelling work regarding hail impact on composite laminates, performed the last five years at Swerea SICOMP.

Ice balls of different sizes and velocities have been shot with an air gun on composite laminates of different thickness and reinforcement architecture. High speed photography and measurement of strain and deflection histories of the laminates have been used to validate the models developed. Models involve dynamic finite element (FE) simulations with cohesive elements to allow for delamination in the laminate, and simplified but fast analytical models. The experimental response has also been compared with predictions from the FE model and the analytical models using various material models of the ice. FE models using a calibrated elastic-plastic ice model are capable of accurately predicting the response and delamination initiation, while the current analytical models are unable to simulate the initial part of the impact.

A main conclusion is that delamination occurs at a very early stage of the impact (first 10-50 microseconds) where three-dimensional wave propagation and the initial elastic-plastic behaviour of the ice are important. Closed form models are capable of predicting the peak contact stresses at the first instance of contact, but further work is required to allow simulation of the decay of contact stresses observed in the FE simulations.

**Keywords** Aircraft; Composite materials; Hail; Impact, Impact damage

## 1. Introduction

Hail and bird impact on engines and leading edges of wings and tail of aircraft in flight is a serious concern for designers due to the relatively high impact velocities. Impact by large birds is normally the most severe case, but will usually immediately be noticed and addressed. In contrast hail impact is relatively common, involves multiple impact sites and the resulting damage will in many cases remain undetected. A thorough, but fairly old review of the topic was given by Souter and Emerson (1952). Some examples of subsequent work may be found in (Anghileri et al., 2005).