# Modelling damage evolution of fibre metal laminates subjected to projectile impact

**†*Z.W. Guan[1,2], J. Zhou[1] and W.J. Cantwell[3]**

[1]School of Engineering, University of Liverpool, Brownlow Hill, Liverpool, L69 3GH, United Kingdom
[2]Department of Mechanics, School of Architecture and Environment, Sichuan University, Chengdu 610065, PR China
[3] Aerospace Research and Innovation Center (ARIC), Khalifa University of Science, Technology and Research (KUSTAR), Po.Box127788, Abu Dhabi, UAE.

*Presenting author: zguan@liv.ac.uk
†Corresponding author: zguan@liv.ac.uk

## Abstract

Fibre metal laminates (FMLs) are multi-layered materials with various stacking arrangements of aluminium alloy layers and fibre-reinforced composite layers. FMLs, such as GLARE (glass fibre/aluminium) and CALL (carbon fibre/aluminium), have attracted the interest of a number of aircraft manufacturers. For example, GLARE is being used in the manufacture of the upper fuselage of the A380, an aircraft that is capable of carrying up to 700 passengers. However, with such composite materials being more widely used, an on-going concern is the effect of foreign object impacts on their mechanical properties. An example of impact is that of an aircraft underbelly or wing impacted at high velocity during take-off and landing by stones and other small debris from the runway. Another example of impact is during the manufacturing process or during maintenance, where tools can be dropped on structures at low velocity. In this case, even though the velocity may be low the drop mass of the tool is frequently large. In this paper, 3-D nonlinear finite element models are presented to simulate perforation failure of FMLs subjected to projectile impact. Here, the modified Hashin's 3D failure criteria are developed with consideration of rate-dependent effect. In addition, rate-dependent damage evolution laws are implemented in the modelling. Also, the rate-dependent plastic damage and Johnson-Cook failure criteria are used to simulate on-set damage and subsequent damage evolution of aluminium subjected to impact. Reasonably good correlation is obtained between the simulated and experimental results, in terms of load-displacement relationships and the corresponding deformation and failure modes. Contribution of the aluminium in FMLs on impact resistance and perforation energy was also assessed and discussed.

**Keywords: Fibre reinforced composites, aluminium alloy, fibre metal laminate, project impact, finite element, Hashin's 3D criteria**