

BALLISTIC DAMAGE IN CARBON/EPOXY COMPOSITE PANELS

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Abstract. Ballistic tests were carried out using carbon/epoxy composite panels and standard ball munitions. Impact and residual velocities of the projectiles and damage area, including delamination, of the test panels were measured. FATEPEN prediction and Dyna3D simulation were conducted. Residual velocities and hole areas predicted by FATEPEN are comparable to, but do not accurately agree with, the measured residual velocities and the visible damage areas on the specimens. Residual velocities predicted by Dyna3D are closer to the measured velocities. Similar to the FATEPEN prediction, hole areas predicted by Dyna3D are comparable to the visible damage areas on the specimens. Delamination areas predicted by Dyna3D appear to agree with the measurement reasonably well. Hence Dyna3D appears to be a useful tool for evaluation of delamination and thus structure residual strength of composite panels after ballistic impact.

NOMENCLATURE

A_d	Damage area
A_{de}	Damage area with both visible damage and delamination
A_{dv}	Visible damage area
C	Calibre of projectile
E	Kinetic energy transferred from projectile to test panel during projectile penetration
T	Thickness of test panel
m_d	Mass of debris
m_p	Mass of projectile
v_i	Impact velocity of projectile
v_r	Residual velocity of projectile after perforation
v_{50}	Ballistic limit velocity
v_{50est}	Ballistic limit velocity estimated using Equations (1) and (2)
α	Oblique angle

INTRODUCTION

Owing to their superior structural performance (such as high strength, high stiffness, long fatigue life and low density) polymer composite materials are increasingly used on aircraft. Some recently developed military helicopters (such as the Eurocopter Tiger) have nearly all composite airframe structures. A large percentage of the composite materials used on aircraft are carbon-fibre polymer materials.

Due to the nature of their mission, military helicopters are vulnerable to ballistic impact damage from small arms on the battlefield. The performance of carbon-fibre polymer materials, in terms of their ability to protect the occupants and internal systems of the aircraft (or armour effectiveness), and their structural integrity after ballistic impact is an important concern for defence research.

Ballistic experiments and numeric simulations were recently carried out at the Australian Defence Science and Technology Organisation (DSTO) to investigate the armour effectiveness and ballistic damage size in carbon/epoxy composite panels. The preliminary results of this investigation are summarised in this paper.

PROCEDURES

Experiment

The carbon/epoxy material used in this work was 5-shaft, satin weave, fabric prepreg (the relevant properties are listed in Table 1). The test panels were made with four different nominal thicknesses, namely 1.28 mm (4 plies), 2.57 mm (8 plies), 3.83 mm (12 plies) and 6.42 mm (20 plies), all with quasi-isotropic lay-ups. The areas of these panels were 100 mm × 100 mm for perpendicular impact or 30° oblique impact and 100 mm × 150 mm for 60° oblique impact.

In the tests 5.56 mm (SS109), 7.62 mm (F4) and 12.7 mm (F1) ball munitions were shot from rifle guns to the centre of the composite panels that were clamped in fixed rigid frames. The variation of the projectile velocities was achieved by using different amount of propellant in the cartridges.

The impact and residual velocities of the projectile were measured using two chronographs installed in front of and behind the target, respectively. After ballistic tests, the penetration hole sizes (visible damage) on the test panels were measured. The delamination areas around the holes were assessed using both tap test and ultrasonic C-Scan methods.

Simulation

Three approaches are commonly utilised in the simulation of ballistic penetration of armour, namely, empirical methods, simplified analytical models and finite element numerical modelling. Numerous research reports with these approaches have been published [1-3]. However, most of them involve metal armour materials, some involving other materials such as ceramic or Kevlar/fibreglass composites, but few involving carbon/epoxy composites. Two simulation tools available to the authors were used in this study; namely the FATEPEN (Fast Air Encounter Penetration) package [4] that is a set of fast-running algorithms based on a combination of simplified analytical and empirical models, and the Dyna3D explicit finite-element software [5]. Both of them contain models for carbon/epoxy composite materials.

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