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Dynamic fracture in carbon-fibre composites: Air-blast loading

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Abstract

In this study a response of a 2x2 twill weave T300 carbon fibre/epoxy composite flat plate specimen resultant air blast dynamic response observed in is examined, using a combination of non-invasive analysis techniques. The study investigates deformation and damage following air blasts with incident pressures of 0.4 MPa, 0.6 MPa and 0.8 MPa, and wave speeds between 650m/s and 950m/s. Digital image correlation was employed to obtain displacement data from the rear surfaces of the specimens during each experiment. 3D x-ray tomography was used to visualize the resultant internal damage within the samples. It was shown that the global deformation and transitions in curvature of each specimen appear to be similar with varying out-of-plane displacements. Damage was observed to propagate from the rear surface of the specimens through to the front surface as the air blast magnitude increased.

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Keywords: carbon-fbre composites; air blast; damage; computed tomography

1. Introduction

A use of fibre-reinforced composites (FRCs) has increased across many areas of application including automotive, aerospace, naval, defence, energy and sport; dynamic loading regimes in all these areas are extremely likely (Silberschmidt, 2016). Therefore, understanding deformation, damage and fracture processes in FRCs under conditions of dynamic loading becomes important. Our study is limited to analysis of air-blast loading conditions, which may occur at close-proximity to explosions or sudden pressure increases.

There was a significant amount of prior research focused at understanding behaviour of fibre-reinforced composites (Langdon et al., 2014) under air-blast loading conditions (LeBlanc et al., 2007; Tekalur et al., 2008). Typically, the analysis of the resultant damage is limited to visual inspection of external surfaces, or use of invasive techniques to study internal damage that could introduce additional damage making the investigation difficult and inconclusive.

This paper describes the experimental case studies, in which carbon fibre/epoxy specimens were subjected to air-

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blast/shockwave loading in order to compare and contrast the resultant deformation and damage processes observed using noninvasive techniques such as digital image correlation and high-precision X-ray micro computed tomography (CT).

2. Experimental Setup

2.1. Materials and Specimens

The carbon-fibre-reinforced epoxy specimens, measuring approximately 195 mm × 195 mm with a thickness of 5.6 mm were fabricated from 10 plies of carbon-fibre fabric, pre-impregnated with a toughened epoxy matrix (IMP530R). The 10 plies were formed to a laminate consisting of 2 surface (external) plies (T300 3K) and 8 central bulking plies (T300 12K), with a 0°/90° layup configuration; the specimens have a theoretical density of 1600 kg/m^3. All specimens were manufacture using the autoclave process, cured at 120°C with a 1.5°C/min ramp rate and a soak time of 160 minutes at a pressure of 90 psi under vacuum.

2.2. Shock Tube Setup

In the undertaken experimental programme, the composite specimens were positioned vertically on a three-point bend-style fixture that consisted of two (slightly rounded) knife edges located 152.4 mm apart (as shown in Figure 1). A rubber band was used to keep the specimen firmly against the knife edges, positioned vertically on the fixture. The shock-tube apparatus (8 m in length) consisted of a driver, a diaphragm and a driven section, which produced the air-blast shockwave by pressurising the driver section up to a critical pressure, at which the diaphragm ruptures creating a dynamic pressure-wave profile. The muzzle of the shock tube, with an inner diameter of 76.2 mm, was moved towards the specimen until there was only a paper-thin (approximately 0.1-0.2 mm) gap between the specimen and the muzzle. Pressure sensors located towards the end of the muzzle recorded the shockwave profile that was acquired in the process of loading.

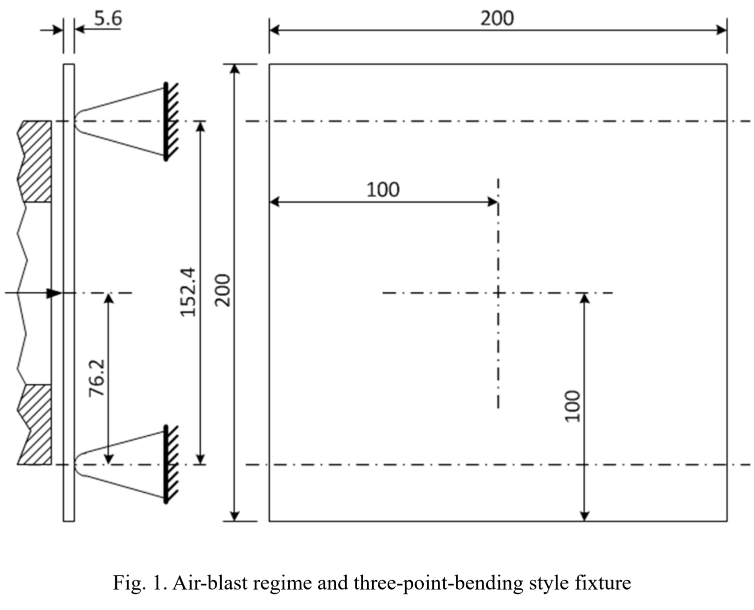

Fig. 1. Air-blast regime and three-point-bending style fixture

The deformation process of the composite plate was captured using three cameras (Photron SA1, Photron USA, Inc., CA, USA), with two cameras recording at 28,800 fps viewing the rear surface of the specimen for implementation of Digital Image Correlation (DIC) using the VIC-3D (Correlated Solutions) system. A third camera, also recording