The ballistic impact response and damage of 3D woven textiles based on glass and carbon fiber

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Introduction

A series of 3D woven textiles have been subjected to impact at ballistic speeds with a series of projectile types. As shown in Figure 1, the textiles differ in the degree of interconnections between the nominal layers and the objective was to identify an optimum textile configuration based on the ability of the resulting composite to provide a one hit ballistic protection (measured by the v50 value) and the multi-hit capability of the materials which is based on the extent of dame suffered in any one impact event.

In contrast to a number of studies devoted to the unidirectional composite structures and even though there is a rapidly growing interest in incorporating textile composites in aerospace, marine and armor system industries, there are very few studies related to the dynamic response, damage and failure prediction under dynamic load of textile composites [1].

It is a well-known fact that the composite structures are highly vulnerable to the low- and high-velocity impacts and blast pressures: more so than the metallic components, which develop some signs of damage under impact loads, and the damage in these structures can be detected easily. The impact-induced damage in the composites, on the other hand, is one of very difficult problems to be analyzed, because the micro-damage of composite structures can occur even under impacts that have low energy. In general, these impact loads can induce structural damage that consists of delamination, matrix cracking and fiber breakage in composites. Among these damage modes, the transverse matrix cracking is a fundamental problem that can lead to a significant strength reduction and, in some conditions, even to a catastrophic failure [1, 2].

Results and Discussions

The behaviour of the panels is modelled using standard methods to identify what features of the textile composite are important (e.g. surface stiffness). It is shown that the one-off ballistic stopping power of a 3D textile composite is no better than that of comparable 2D fabrics composites, but that the damage areas for non-penetrating impacts are significantly reduced leading to presumed improvements in multi-hit capabilities.

In the results, there are strong indications that the best 3D fabric construction is one where the volume fraction of the external layers is maximised and where the interplay connections are reduced between the surface layers and the bulk of the composite.

Figure 2 below shows the ballistic limit (BL for a range of 3D composites versus similar data for plain woven composites and damage area (DA) for the same materials.

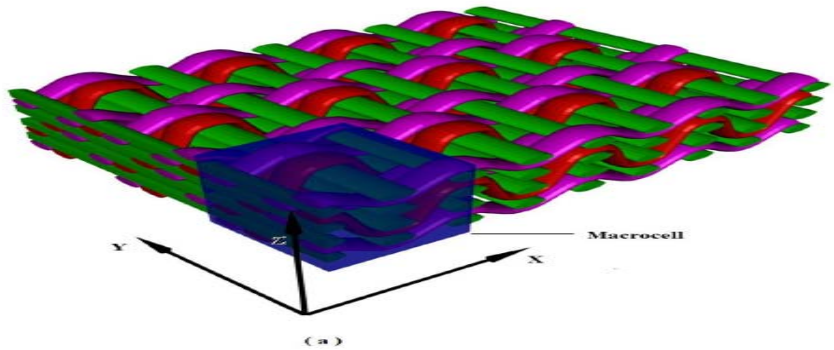
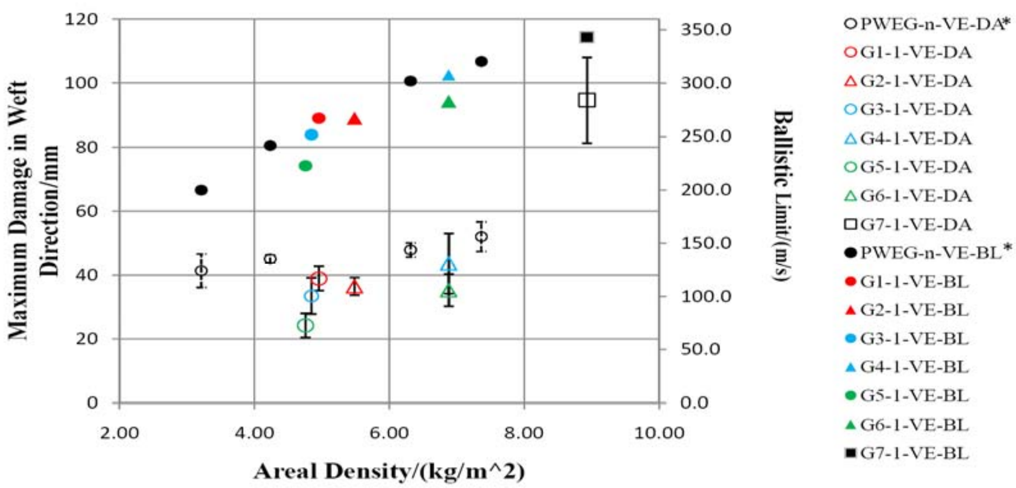


Figure 1: A typical 3D fabric used in this work.



(a)

Figure 2: The ballistic limit (BL) for a range of 3D composites vs similar data for plain woven composites and damage area (DA) for the same materials.

Conclusions:

The data in Figure 2 shows a clear trend in the ballistic limit (BL for a range of 3D composites when compared to similar data for plain woven composites and damage area (DA) for the same materials. As expected, the result gives a better understanding of the behavior of 3-D textile composite structures under various dynamic loading cases. It would interest to see how these results compare in the modelling and analysis of dynamic behavior and failure of 3-D woven textiles composite structures**.**

Future work:

Future work will involve modeling of dynamic behavior and failure of 3-D woven textiles composite structures subjected to ballistic impact type loads. The dynamic analysis would be based on a three-level hierarchical approach: a micro-mechanical unit cell analysis, a layer-wise analysis accounting for transverse strains and stresses, and a global structural analysis based on the multi-layered anisotropic plates.

Reference:

1. Hae-Kyu Hur, Jungsun Park and Rakesh K. Kapania, "Ballistic Resistance of 3-D Orthogonal Woven Textile Composites with Helically Twisted Z-Strands" 50th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2009-2358 4 - 7 May 2009, Palm Springs, California.

2. L Daniel, A. Ahmanaya and P J Hogg, "The Effect of Secondary Through-Thickness Stitching on Damage and Energy Absorption in Glass and Carbon Fibre Laminates." Damage and Fracture Mechanics, QMW- University of London, UK, June 1999