Composites: Part B 40 (2009) 413–415

Contents lists available at ScienceDirect

Composites: Part B

journal homepage: www.elsevier.com/locate/compositesb

Editorial

Blast/impact on engineered (nano)composite materials

Extreme loading conditions such as blast or ballistic impact have been a topic of intensive research for years. This type of incident loading can be found in both military equipment and civilian structures. Unlike static loading, blast or ballistic impact usually leads to sudden loss of structural capacity or functionality as well as loss of lives. Fiber or particle reinforced composite materials have been used in almost all man-made engineering structures such as the space shuttle, aircraft, ships, vehicles, pressure vessels, piping, bridges, buildings, oil platforms, etc., due primarily to their high specific strength and stiffness, tailor-ability, and multifunctionality. With the continuously increasing use of composite materials in both military equipment and civilian structures, together with the growing threat from blast or fragmentation impact, understanding blast or ballistic impact response and finding ways of improving damage tolerance are critical issues facing academia, governmental agencies, and industry.

It has been found that blast or impact response of composite materials is a very complex process, which involves stress wave transfer, damage creation and propagation, heat and sound transfer, phase change, etc. In order to understand the impact response and damage mechanism so that impact tolerant structures can be designed, multiscale modeling from atomistic to structural level is mandatory. Because of the highly coupled, multidamage mode, and multiscale nature of the problem, closed-form solutions are improbable. The combination of physics based theoretical models and advanced numerical simulation, is a promising alternative approach.

Traditionally, fiber reinforced composite materials have been used in the form of laminated composites. It is well known that laminated composites are vulnerable to transverse impact incident due to the creation and propagation of various types of damage, in particular, delamination. With the recent advancements in the textile industry, 3D woven or z-pinned fabric reinforced composite structures have been proposed as an alternative to laminated composites due to their improved resistance to delamination. However, there is currently a lack of detailed understanding of the impact response and residual structural capacity. There is a plenty of rooms left for intensive and extensive study in this area in order to fully utilize the advantages of these types of novel structures for impact and/or blast tolerance.

This special issue of “Blast/impact on engineered (nano)composite materials” responds to the challenge by reporting the state-of-the-art and cutting-edge studies in this area. Seventeen papers from leaders in this area are included in this special issue. The papers deal with a broad spectrum of topics from nano structures to sandwich structures, from molecular-length scale to structural length scale, and from theoretical modeling, finite element simulation, to experimental testing. Fundamentally, the papers can be categorized into two groups. The first group deals with multiscale modeling of blast/impact response and the second group focuses on testing and numerical modeling of 3D woven or z-pinned composite sandwich structures under low velocity to ballistic impact incidents.

1. Group 1: Multiscale modeling of blast/impact response

1.1. Paper 1

“Multiscale Aggregating Discontinuities Method for Micro–Macro Failure of Composites”

Song and Belytschko described the application of a multiscale method, called the multiscale aggregating discontinuities (MAD) method, to the failure analysis of composites. Two distinct features of the MAD method are the use of perforated unit cells, and the extraction of coarse-grained failure information.

1.2. Paper 2

“Thermodynamically Consistent Coupled Viscoplastic Damage Model for Perforation and Penetration in Composite Materials”

Voyiadjis, Deliktas, and Palazotto provided the theoretical framework for the multiscale micromechanical modeling of the perforation and penetration problem in laminated metal–matrix composite materials subjected to impact loading.

1.3. Paper 3

“Simulation of Perforation and Penetration in Metal–Matrix Composite Materials Using Coupled Viscoplastic Damage Model”

Deliktas, Voyiadjis, and Palazotto presented the nonlocal computational aspects for the micromechanical based perforation and penetration problem of MMCs due to high impact loading, with the overall characteristic response of the impacted plate due to bending, dishing and a cone shaped macrocrack in the material.

1.4. Paper 4

“Modeling effects of crystalline microstructure, energy storage mechanisms, and residual volume changes on penetration resistance of precipitate-hardened aluminum alloys”

Clayton used a nonlinear crystal elastoplasticity model in a multiscale context to investigate effects of lattice orientation and defects on the ballistic performance of an aluminum alloy.

1.5. Paper 5

“Attachment mode performance of network-modeled ballistic fabric shielding”

By using a stochastic approach based multiscale model, which was shown to be critical to capturing accurate results, Powell and Zohdi

1359-8368/$ - see front matter
doi:10.1016/j.compositesb.2009.05.002

predicted that ballistic fabric pinned at the corners and impacted by a projectile absorbed a greater amount of energy prior to failure than fabric fixed along either 2 or 4 sides.

1.6. Paper 6

"Interatomic potentials for atomic scale modeling of metal–matrix particle reinforced nanocomposites"

Dongare, Zhigilei, Rajendran, and LaMattina proposed an Angular-dependent-Embedded Atom Method (A-EAM) framework, which was based on the combination of well-established and thoroughly tested potentials developed for pure components and, therefore, provided an attractive alternative to the design of new alloy potentials with original functional forms.

1.7. Paper 7

"Multiscale Ballistic Material Modeling of Cross-plied Compliant Composites"

Grujicic, Arakere, He, Bell, Glomski, and Cheeseman used a multi-length-scale approach to model transient dynamic response of prototypical $0^\circ/90^\circ$ *cross-plied unidirectional ultra-high molecular weight polyethylene (UHMWPE) filament based armor-grade composites and found that the model realistically accounted for the experimentally observed ballistic resistance of these materials to different threats and clearly delineated the main stages of single-hit interactions between bullets/fragments and the armor test-panels.*

1.8. Paper 8

"Computational Model for Predicting Nonlinear Viscoelastic Damage Evolution in Materials Subjected to Dynamic Loading"

A nonlinear viscoelastic cohesive zone fracture model was implemented into an explicit finite element formulation by Souza, Kim, Gazonas, and Allen, which was used to examine two dynamic fracture example problems: the first validated the code using a one-dimensional analytical solution for dynamic viscoelastic debonding, and the second predicted dynamic fracture propagation in the double cantilever beam test with a viscoelastic cohesive zone.

1.9. Paper 9

"Predicting Mesh-Independent Ballistic Limits for Heterogeneous Targets by a Nonlocal Damage Computational Framework"

By inappropriating the current local thermo-viscoplasticity and rate-dependent damage or fracture theories, Abu Al-Rub and Kim predicted the ballistic limit velocity in high speed impacts of heterogeneous ductile targets such that an incorporation of an explicit length scale parameter through the nonlocal theory was imperative.

1.10. Paper 10

"A Multiscale Model for Coupled Heat Conduction and Deformations of Viscoelastic Functionally Graded Materials"

Using a multiscale model incorporating time and temperature dependent behaviors of the constituents and microstructural features, Khan and Muliana predicted the overall coupled heat conduction and deformation of functionally graded materials.

1.11. Paper 11

"A Multi-Objective Optimization Approach for Design of Blast Resistant Composite Laminates Using Carbon Nanotubes"

Using a multi-objective optimization approach, Reda Taha, Colak-Altunc and Al-Haik found that optimal distribution of carbon nanotubes in carbon composite interface enables producing blast resistant carbon composites.

2. Group 2: Modeling and testing of 3D woven or z-pinned composite structures

2.1. Paper 12

"Modeling and Predicting the Compression Strength Limiting Mechanisms in z-pinned Textile Composites"

Huang and Waas developed a predictive model for the compression strength of axial tows that were weakened by z-pin insertion, which can be used to predict the compression strength allowable of z-pinned textile composites.

2.2. Paper 13

"Effect of Z-Yarns on the Stiffness and Strength of Three-Dimensional Woven Composites"

Rao, Sankar, and Subhash seamlessly integrated geometric and mechanistic aspects of 3D woven composites in a unified finite element based micro-mechanics framework to obtain reliable estimates of stiffness and strength properties.

2.3. Paper 14

"A unit cell approach of finite element calculation of ballistic impact damage of 3D orthogonal woven composite"

Sun, Liu, and Gu conducted ballistic impact damage simulation of 3D woven composite using the unit cell approach.

2.4. Paper 15

"Low-Velocity Impact Response of Sandwich Composites with Nanophased Foam Core and Biaxial ($\pm 45^\circ$) Braided Face Sheets"

Bhuiyan, Hosur, and Jeelani infused carbon nanofibers (CNF) into closed cell foams and altered the foaming process, resulting in smaller cell sizes and increased cell wall thickness, and when used in sandwich constructions, improved the damage tolerance in low-velocity impact scenario and also reduced the damage size.

2.5. Paper 16

"Transverse impact damage and energy absorption of 3D multi-structured knitted composite"

Sun, Hu, and Gu reported the transverse impact behavior of a new type of 3D multistructured knitted composite both in experimental testing and finite element simulation.

2.6. Paper 17

"Damage modes in 3D glass fiber epoxy woven composites under high rate of impact loading"

While the z-yarns may be effective in limiting the delamination damage at low loads and at low rates of impact, Walter, Subhash, Sankar, and Yen found that, at high loads and high loading rates delamination continues to be the dominant failure mode in 3D woven composites.

We would like to take this opportunity to express our sincere thanks to the contributing authors for their meticulous preparation of the papers and, in particular, the reviewers for their prompt and high quality review. We would also like to thank Elsevier for providing a platform of publishing this special volume in a timely manner.

Bruce LaMattina
U.S. Army Research Office, P.O. Box 12211, Research Triangle Park, NC 27709-2211, USA
Tel.: +1 919 549 4379.
E-mail address: Bruce.LaMattina@us.army.mil

Guoqiang Li
Department of Mechanical Engineering, Louisiana State University, Baton Rouge, LA 70803, USA
Tel.: +225 578 5302; fax: +1 225 578 5924.
E-mail address: guoli@me.lsu.edu

David Hui
Mechanical Engineering Department, University of New Orleans (UNO), New Orleans, LA 70148, USA
Tel.: +1 504 280 6192.
E-mail address: dhui@uno.edu