Improving Damage Tolerance & Dynamic Energy Absorption Capacities in Laminated Woven Composites using Crimp Imbalance & Crimp Imbalance Gradients

NAVSEA WARFARE CENTERS NEWPORT
Office of Naval Research Science & Technology

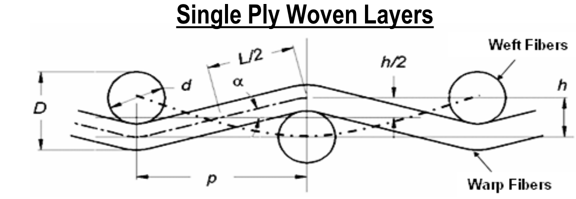
Problem:

Unlike metals, fiber reinforced/polymer matrix (FRP) composites are less damage tolerant and are susceptible to many failure mechanisms that can limit their load carrying and energy absorption capacities (i.e.; fiber breakage, fiber buckling, matrix shearing, matrix cracking, fiber/matrix delamination, environmental degradation, free edge effects, etc.)

Background:

Crimp content, *C*, is the measure of a fiber's waviness when woven. It is the ratio of the length when removed from the weave and straightened to its "*as-woven*" length. The ratio of crimp contents, ζ, is defined as the ratio of the High Crimp Content (HCC) fibers (often the warp) to the Low Crimp Content (LCC) fibers (often the weft). When both fiber families have identical crimp contents, ζ =1.0 and the weave is termed crimp-balanced (CB) or "*iso-crimped*". Both *C* and ζ are dependent upon fiber weave densities and fiber tensions during weaving.

Cross Sections of Crimp-Balanced & Crimp-Imbalanced Single Ply Woven Layers



Crimp-Balanced (CB) (iso-crimped)

Crimp-Imbalanced (CI)

Solution:

As an architectural parameter, ζ can influence both static and dynamic behaviors of FRP woven composites and can increase their structural integrity, damage tolerance and survivability against dynamic events such as blast, UNDEX shock, implosion, wave slap and ballistic/fragment impact.

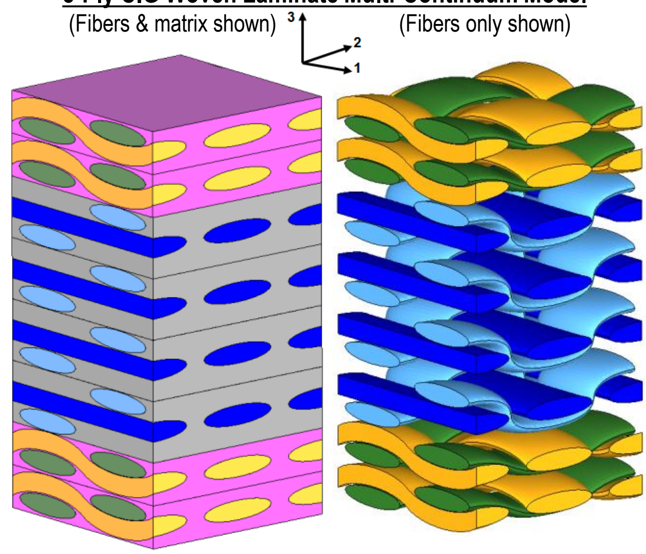
Crimp-imbalanced (CI) architectures and crimp-imbalanced gradients (CIG's) provide opportunities for enhancing performance over CB laminates by enabling the selective decoupling of stress wave propagations along fiber axes in the 1-2 plane and along the 3-3 axis.

By decoupling the stress wave arrival and dispersal times, strain energy densities are temporally and spatially reduced at critical locations (i.e.; structural joints, etc.) to ensure continued functionality of the fiber and matrix materials including the cohesive bonds at their interface.

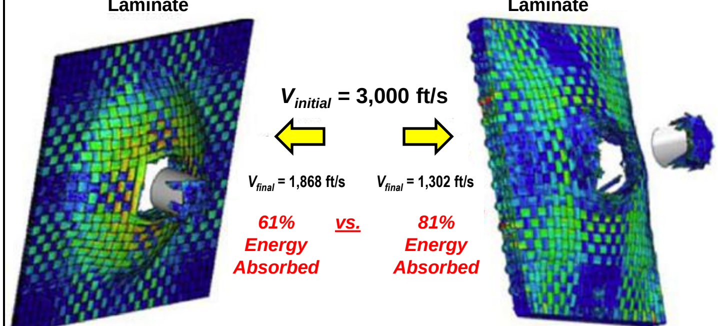
Approach: Combined Physics-Based Modeling & Testing

8-Ply CIG Woven Laminate Multi-Continuum Model

(Fibers & matrix shown) (Fibers only shown)



Example: Improved Dynamic Energy Absorption of 4-Ply Target Subject to Fragment Impact



U.S. Patent No. 8,555,472, others pending.

Principal Investigator: Paul V. Cavallaro
Tel: 401-832-5082
Email: paul.cavallaro@navy.mil
Organization: NUWCDIVNPT, Code 7112

Potential Benefits to Fleet & Applications: Improved structural performance, survivability and reliability.

Bow Domes,
Tail Cones,
Hulls,
Masts,
Personnel Protection,
etc.