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SCIENCE DIRECT®
Composites: Part B 35 (2004) 447–450
composites Part B: engineering
www.elsevier.com/locate/compositesb

Editorial

Marine Composites: Foreword

Composite materials are being used increasingly in marine structures due to their many advantages. However, the unique and hostile marine environment, with the presence of sea water and moisture, temperature extremes, time-dependent three-dimensional loading due to wave slamming, hydrostatic pressure, and other factors, gives rise to significant challenges for designers of composite marine structures. Additional requirements on Naval structures include the ability to withstand highly dynamic loading, due to weapons impact, or to air or underwater explosions.

The Solid Mechanics Research Program at the Office of Naval Research (ONR) supports research on the mechanical behavior of structural materials, providing the scientific basis for the effective design and utilization of affordable Naval structures. Today, the major focus is on marine composites and composite sandwich structures.

This research program deals with deformation, damage initiation, damage growth, failure and instability/buckling in glass fiber and carbon fiber reinforced composites and composite sandwich structures subjected to static, cyclic, and dynamic multi-axial loading conditions in severe environments. The main objectives are to understand the mechanics and physics of the processes involved, and to establish physically based models with predictive capabilities. Areas of emphasis include constitutive behavior, failure modes and mechanisms, failure criteria, environmental effects, dynamic response, and structural effects. Additionally, concepts for enhancing the mechanical properties of marine composites through the introduction of nanoparticles are being explored.

This Special Issue on "Marine Composites" contains 27 papers from leading researchers in mechanics of composite materials and sandwich structures supported by the ONR Solid Mechanics Program. The papers are grouped into the broad areas of environmental effects, deformation and failure, structural response, and dynamic effects. Examples of current research activities include:

Environmental Effects

"**Sea Water Effects on Foam-Cored Composite Sandwich Layups**"

Xiaoming Li, and Y. Jack Weitsman

"The article summarizes a long-term investigation on sea water effects on closed-cell polymeric foam core sandwich composites. The major finds are that although sea water penetrates only several of the outer "rows" of the cellular structure, this suffices to degrade that material and reduce the debond toughness at the core/facing interface."

"**Effects of the Marine Environment on the Interfacial Fracture Toughness of Pvc Core Sandwich Composites**"

David R. Veazie, Kito Robinson, and Kunigal Shivakumar

The sensitivity of the interfacial fracture toughness to initiate crack creation and environmental exposure implies that these effects must be accounted for in test methods or predictive schemes to estimate face-sheet/core interfacial failure or remaining life of sandwich composites.

"**Thermomechanical Modelling the Fire Properties of Fibre-Polymer Composites**"

A.P. Mouritz, Z. Mathys, and C.P. Gardiner

Simple-to-use mechanical models for predicting the post-fire (residual) tension, compression and flexural properties of polymer composites are presented and validated.

Deformation and Failure

"**Effective Properties for Single Size, Rigid Spherical Inclusions in an Elastic Matrix**"

Richard M. Christensen

The modulus type effective or average properties are determined for the case where single size, rigid, spherical particles are dispersed in an elastic matrix over the full range of possible volume fraction for the inclusions, up to the limit of random packing.

"**Sublaminate-Based Lamination Theory and Symmetry Properties of Textile Composite Laminates**"

Jyi-Jiin Luo, Isaac M. Daniel

A sublaminate-based lamination theory was developed for textile composites based on the properties of the single fabric layer including the effects of weave pattern on symmetry and balance.

1359-8368/$ - see front matter © 2004 Published by Elsevier Ltd.
doi:10.1016/j.compositesb.2004.05.001

"**Accelerated Testing for Long-Term Durability of GFRP Laminates for Marine Use**"

Yasushi Miyano*,[1], Masayuki Nakada* and Naoyuki Sekine**

The long-term flexural fatigue life of plain woven glass fiber/vinyl-ester (GFRP) laminates for conventional marine use was predicted using our proposed accelerated testing methodology based on the time-temperature superpositon principle.

"**Macro and Micro Deformations in a Sandwich Foam Core**"

Sheng Chang, Dan Hong and Fu-Pen Chiang

Random speckle methods are applied to mapping the detailed full field deformation of sandwich foam cores under various loading condition.

"**Static Indentation and Unloading Response of Sandwich Beams**"

Dan Zenkert, Andrey Shipsha, Karl Persson

A response of foam-core sandwich beams to static indentation and followed unloading has been analytically modelled and verified using the FE analysis and experiments.

"**Collapse of Clamped and Simply Supported Composite Sandwich Beams In Three-Point Bending**"

V.L. Tagarielli, N.A. Fleck and V.S. Deshpande

The authors focused their attention on the effect of fully clamped boundary conditions on the bending response of sandwich beams comprising composite faces and a polymer core; their analytical models, validated via numerical simulations and experimental evidence, show that the mechanisms of deformation and failure are substantially different from those for simply supported beams: clamped beams undergo stretching due to finite deflection, and therefore the ductility of the faces sets the ultimate strength and the energy absorption of the structure.

"**Compressive Strength After Impact of CFRP-Foam Core Sandwich Panels in Marine Applications**"

Peter H. Bull and Frederik Edgren

A plastic micro buckling model is used to predict compressive strength after impact of non-crimp fabric carbon fiber faced sandwich panels and digital speckle photography is used to track damage growth during residual strength testing.

"**Response of Sandwich Composites with Nano-Phased Cores under Flexural Loading**"

Hassan Mahfuz, Muhammad S. Islam, Vijaya K. Rangari, and Shaik Jeelani

The core of a sandwich composite can be modified by infusion of nanoparticles, and the performances of the nanophased core and sandwich composite are found to be significantly superior to their neat counterparts.

"**Fracture Analysis of Facesheets in Sandwich Composites**"

H. Jiang, Y. Huang, C. Liu

The shear-lag model establishes that, for a given ratio E_t/E_f of the elastic moduli in the transverse and fiber directions of the face-sheets in sandwich composites, there exists a critical face-sheet thickness above which crack blocking is achieved and crack growth is prevented.

"**Imaging of Damage in Sandwich Composite Structures using a Scanning Laser Source Technique**"

Pavel A. Fomitchov, Alexey K. Kromin, Sridhar Krishnaswamy and Jan D. Achenbach

The scanning laser source technique (SLS) technique is an optical inspection technique that uses a pulsed laser source to thermoelastically generate ultrasound; it has significant advantages over conventional methods and can be used to map damage in composite materials.

"**Acoustic Emission Based Tensile Characteristics of Sandwich Composites**"

A. Quispitupa, B. Shafiq, F. Just, D. Serrano

This paper presents acoustic emission based static and fatigue tensile characteristics of sandwich composites and AE based stiffness reduction lifetime model.

Structural Response

"**Conict Between Sandwich Buckling Formulas and Modification of Standard Computational Algorithm for Finite Strain**"

Zdenek P. Bazant and Alessandro Beghini

While it is already known that different theories for sandwich buckling are equivalent under a certain transformation, the paper shows that small-strain linear elastic shear properties of the core are applicable only within the framework of Engesser-type theory, which is substantiated by FEM results.

"**Experimental Investigation of Compression Failure of Sandwich Specimens with Face/Core Debond**"

Vinod Vadakke and Leif A. Carlsson

This study presents experimental observations detailing the compressive failure mechanism of composite sandwich columns containing face/core debonds, and quantifies the reduction of strength due to the face/core debond for a large range of PVC foam core densities.

"**Elasticity, Shell Theory and Finite Element Results for the Buckling of Long Sandwich Cylindrical Shells under External Pressure**"

Jea-Hyeong Han, George A. Kardomateas and George J. Simitses

An elasticity solution to the problem of buckling of sandwich long cylindrical shells subjected to external pressure is presented, along with shell theory results with and without accounting for the transverse shear effect and with finite element results by use of a shear deformable shell element and a solid 3D (brick) element.

"**Similitude of Sandwich Panels with 'Soft' Core in Buckling**"

Y. Frostig and G.J. Simitses

Structural similitude theory is employed to design a small scale model and to project the test results of the small model in order to predict the behavior of the large prototype, through the use of derived similarity conditions.

"**Analysis of Tongue and Groove Joints for Thick Laminates**"

Karel Matous and George J. Dvorak

The authors present a finite element evaluation of stress distribution in the adhesive and adherends of a tongue and groove joint of a thick glass-vinyl ester laminate to a steel plate loaded by both in-plane tension and transverse bending, and describes scaling of the results to laminates of arbitrary thickness; stress relaxation in the adhesive is taken into account.

"**Local Effects in the Vicinity of Inserts in Sandwich Panels**"

Elena Bozhevolnaya, Anders Lyckegaard, Ole T. Thomsen and Vitaly Skvortsov

The paper presents and verifies closed-formed analytical estimates for the stress concentrations near circular inserts in sandwich panels.

"**Experimental Investigation of Local Bending Effects in the Vicinity of a Junction Between a Straight Sandwich Beam and a Curved Sandwich Beam**"

Anders Lyckegaard, E. Bozhevolnaya and Ole Thybo Thomsen

The authors investigate the junction between a straight sandwich panel and a curved sandwich panel by high order sandwich beam theory and electronic speckle pattern interferometry.

Dynamic Effects

"**Failure Mode Transition and Energy Dissipation in Naturally Occurring Composites**"

M. Vural and G. Ravichandran

The experimental investigation on the energy absorption capacity and microstructural failure modes of balsa wood (which is a commonly used cellular core material in marine structures) and the evaluation of the unique architectural features of wood cell-walls lead to the conclusion that a biomimetic-based design route may prove to be efficient in the design of multilayered composite energy absorbers particularly in the absence of rigorous analytical and computational tools to analyze large-strain post-failure deformations in tubular composites.

"**A Method for Testing Interlaminar Dynamic Fracture Toughness of Polymeric Composites**"

C.T. Sun and C. Han

From the study of two polymer composite systems, it appears that mode I delamination fracture toughness does not depend appreciably on dynamic loading rate nor on the crack propagation speed up to 1000 m/s.

"**Characterization of the Dynamic Failure Behaviour of a Glass-Fiber/Vinyl-Ester Composite at Different Temperatures by Means of Instrumented Charpy Impact Testing**"

Prof. J.F. Kalthoff

Work is reported on using the instrumented Charpy impact test for characterizing the strength and failure properties of a glass-fiber/vinyl-ester composite showing that this test technique can be used with minimum technical effort in a very simple manner with specimens that can very inexpensively be machined, but giving data that can successfully be used for quantifying the quality of composite materials in surveillance programs for the control of processes such as manufacturing or aging of the material.

Dynamic Wrinkling in Sandwich Beams and Large Aspect Ratio Wide Panels

Victor Birman

The problem of dynamic wrinkling instability in sandwich panels experiencing forced vibrations has been considered; prevention of dynamic wrinkling is important to avoid fatigue damage in the facings and along the facing–core bond.

"**Linear and Non-Linear Dynamic Reponse of Sandwich Panels to Blast Loading**"

Liviu Librescu, Sang-Yong Oh, and Jeorg Hohe

A geometrically non-linear theory of sandwich panels featuring laminated anisotropic face sheets and a weak core are presented, and the dynamic response to underwater and in-air explosions is investigated, and ways to alleviate the intensity of the blasts are discussed.

"**Static and Dynamic Deformation of Thick Functionally Graded Elastic Plates by using Higher-Order Shear and Normal Deformable Plate Theory and Meshless Local Pctrov-Galerkin Method**"

L.F. Qian, R.C. Batra and L.M. Chen

The authors first show that static deformations of a functionally graded plate computed with the 5th-order shear and normal deformable plate theory of Batra and Vidoli agree very well with the analytical solution of the corresponding three-dimensional elasticity equations; they then analyze the transient deformations.

The research covered in this volume should be of interest to anyone involved in marine composites structures, and to those in related technological areas (offshore structures, energy exploration and production, transportation, infrastructure, and aerospace).

We would like to thank the authors for their valuable contributions to the Special Issue on "Marine Composites", the reviewers for their many incisive comments, and Elsevier for their professional and timely publication of this special issue.

Yapa D.S. Rajapakse
Office of Naval Research,
Ship Structures Division,
Arlington, VA 22217-5660, USA

David Hui*
Department of Mechanical Engineering,
University of New Orleans, Lakefront,
New Orleans, LA 70148, USA
E-mail address: dxhme@uno.edu

Available online 11 June 2004

* Corresponding author. Tel.: +1-504-280-6192; fax: +1-504-280-5539.