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Foreword

Marine Composites and Sandwich Structures

Naval structures operate in severe environments, and are designed to withstand complex multi-axial and dynamic loads. 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, provides significant challenges to designers of composite marine structures. Additional requirements on Naval structures include the ability to withstand severe sea conditions and 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) provides the scientific basis for: (i) the effective design of advanced Naval structures with enhanced affordability, stealth, survivability, shock/blast resistance, reliability, and durability, (ii) the assessment of structural integrity, and (iii) the design of structures/platforms for fast ships and sea basing. This program serves as a bridge between materials science research and structural design. The current focus is on the mechanics of marine composite materials and composite sandwich structures (and constituent materials, including new core materials and nanocomposites). The program deals with understanding and modeling the physical processes involved in the response of glass-fiber and carbon-fiber reinforced composite materials and sandwich structures to static, dynamic, cyclic, and multi-axial loads, in severe environments (in the presence of sea water, moisture, temperature extremes, hydrostatic pressure, and high rate loading). Concepts for enhancing the durability of marine composites through the introduction of nanoparticles/nanotubes are also being explored. Research on multifunctional composites seeks to enhance the performance of composite marine structures through the incorporation of additional beneficial attributes.

This special issue on Marine Composites and Sandwich Structures contains twenty five papers from leading researchers in mechanics of composite materials and sandwich structures, supported by the ONR Solid Mechanics Program. These contributions are grouped into five broad areas: mechanical behavior, dynamic response, structural response, nanocomposites, and non-destructive evaluation.

Seven papers in this special issue deal with the mechanical behavior of composite materials and sandwich structures. Issues addressed include durability and life prediction, three-dimensional material characterization, size effects in compression testing, comparative studies of glass/vinylester and carbon/vinylester composites, fatigue models, and multi-scale deformation evaluations in foam core materials. Research on dynamic response, reported in seven papers, deal with experimental investigations of blast effects, progressive damage modeling, high strain rate effects in core materials, effects of transverse core compressibility, and concepts for blast resistance. Topics covered in the area of structural response include modeling delaminations in the presence of material imperfections, functionally graded plates, buckling, thermal response, design of core junctions, and fire resistance. Three papers in nanocomposites cover experimental technique for the visualization of nanoparticle dispersion, buckling of single-walled carbon nanotubes, and thermoplastic/carbon nanotube films for strain sensing. The two papers on non-destructive evaluation deal with low-cost and neural network based techniques.

The editors want to thank the authors for their excellent contributions to this special issue on recent advances in marine composites and sandwich structures research.

List of papers

1. Mechanical behavior

Accelerated testing for long-term strength of advanced CFRP laminates for marine use

Yasushi Miyano, Masayuki Nakada, Jun Ichimura and Eiji Hayakawa

In the paper by Miyano et al., the prediction of long-term flexural strength of CFRP laminates for innovative marine use under water absorption conditions were performed by our developed accelerated testing methodology based on the time–temperature superposition principle.

Three-dimensional characterization of textile composites

Isaac M. Daniel, Jyi-Jiin Luo and Patrick M. Schubel

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Test methods were developed/adapted for complete mechanical characterization of textile composites in three dimensions, and experimental results were compared with theoretical predictions, including those of a newly developed interlaminar failure theory.

Specimen size effect in off-axis compression tests of fiber composites

Qida Bing and C.T. Sun

This paper provides the method for minimizing the specimen size effect in using small off-axis brick specimens for static and high strain rate compressive tests to determine compressive strength and nonlinear rate dependent constitutive models for polymeric fiber composites.

Evaluation of specific properties of glass and carbon/vinyl ester composites

Gowthaman Swaminathan, Kunigal N. Shivakumar and Mathew Sharpe

The paper demonstrated that stitch bonded T700 Carbon fiber/Vinyl ester composites have far superior specific stiffness and strength than glass composites and steel and hence is a material of choice for marine topside structures.

Application of total fatigue life model to T700 carbon/vinyl ester composite

Huanchun Chen, Kunigal N. Shivakumar and Felix Abali

A total fatigue life model developed previously was found to be valid for T700 carbon fiber/vinyl ester composite laminates subjected to mode-I cyclic loading.

Size effect on stress–strain relation of neat polyurethane foam

Fu-Pen Chiang and Yi Ding

Chang, Ding and Chiang provide the first experimental evidence showing the dependence of mechanical properties of foam composites on the size of the specimen used to obtain them.

Helium permeability of coated aramid papers

Monika Bubacz , Andrey Beyle, David Hui and Christopher C. Ibeh

A thin barrier layer of low-weight impregnated aramid paper is used to prevent leakage of gases through a composite sandwich wall of a cryogenic tank; the results of helium permeability tests of different combinations of papers and resins showed excellent barrier behavior.

2. Dynamic response

Mechanical behavior and damage evolution in E-glass vinyl ester and carbon composites subjected to static and blast loads

Srinivasan Arjun Tekalur, Kunigal Shivkumar and Arun Shukla

Our paper deals with the characterization of material and structural behavior under different loading rates and provides a fundamental understanding, through a series of experiments, into the differences in damage evolution and patterns in these two composites under highly transient and controlled shock blast loading conditions.

Modeling damage in polymeric composites

N.M. Hassan and R.C. Batra

The paper by Hassan and Batra uses continuum damage mechanics and the mechanics of materials approach to develop and validate a damage growth model in laminated composites comprised of unidirectional fiber-reinforced laminas. After having found values of material parameters for the AS4/PEEK composite by using experimental findings of Kyriakides et al., model's predictions are found to compare well with experimental results of Weeks and Sun, and of Schoppner and Abrate.

The high strain rate response of PVC foams and end-grain balsa wood

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

Dynamic compression experiments are performed on sandwich cores widely used in marine construction, at strain rates typically attained in shock events; experiments to demonstrate pronounced train-rate sensitivity of these materials.

Impact response of fire damaged polymer-based composite materials

C.A. Ulven and U.K. Vaidya

Ulven and Vaidya considered the post-fire low velocity impact response of marine grade sandwich composites. Their results demonstrated that the energy absorption mechanisms during impact events drastically change with increasing fire exposure because of global stiffness loss. This stiffness loss during impact can be modeled using a simple rule-of-mixtures post-fire property model combined with classical plate theory.

Recent results on the effect of the transverse core compressibility on the static and dynamic response of sandwich structures

Jörg Hohe and Liviu Librescu

Hohe and Librescu used their newly developed theory of sandwich structures, and applied to issues related with the wrinkling, global response and dynamic buckling to time-dependent external loads, as well as to underwater explosions, and results and conclusions instrumental toward the design of advanced sandwich constructions were supplied.

Enhancement of blast resistance of sandwich plates

Yehia A. Bahei-El-Din and George J. Dvorak

Significant improvement in resistance of sandwich plates to blast loading was achieved in new designs which utilize energy absorbing interlayers to shield and reduce compression of the foam core, and associated delamination and failure of the face sheets.

Advanced shock-resistant and vibration damping of nanoparticle-reinforced composite material

Maksim Kireitseu, David Hui and Geoffrey Tomlinson

This research work showed experimental results on nanoparticle/tube-reinforced polymer composite materials that provided advanced shock resistance, impact toughness, lighter, stiffer and enhanced vibration damping of polymer matrix over broader frequency and temperature ranges.

3. Structural response

Delamination in flat sheet geometries with material imperfections and thickness variations

Martin G. Andrews and Roberta Massabò

Martin G. Andrews and Roberta Massabò show that the presence of small delamination damage, consisting of an array of small parallel delaminations, induces phenomena of amplification and shielding of the energy release rate of a main delamination propagating through the damaged area, such damage also leads to modification of the mode ratio.

Functionally graded plates behave like homogeneous plates

Serge Abrate

An anology between the behavior of functionally graded plates and that of homogeneous plates is pointed out and leads to the realization that no new analysis method is needed in order to analyze the behavior of functionally graded plates.

Initial postcritical behavior of sandwich columns with low shear and transverse stiffness

Alessandro Beghni, Zdeněk P. Bažant, Anthony M. Waas and Shiladitiya Basu

Bazant and Beghini show that the postcritical behavior of laminate-foam sandwich column, previously believed to be imperfection insensitive, can in fact exhibit imperfection sensitivity, which follows Koiter's 2/3-power law, provided that the core has very low shear stiffness, and they also validate their analytical formulation by finite element simulations of postcritical response.

Non-linear thermal response of sandwich panels with a flexible core and temperature dependent mechanical properties

Yeoshua Frostig and Ole Thybo Thomsen

A geometrically non-linear high-order sandwich theory has been developed which includes the thermo-mechanical response and temperature dependent material properties. A thorough parametric study demonstrates that the interaction between mechanical loads, temperature induced deformations, and degradation of the mechanical properties due to elevated temperatures, may seriously affect the structural integrity.

Novel design of core junctions in sandwich panels

E. Bozhevolnaya, A. Lyckegaard and O.T. Thomsen

The paper investigates the occurrence and severity of local stress concentrations in sandwich panels with core junctions. A novel core junction design is proposed which significantly improves the static strength as well as the fatigue endurance.

Fire resistance simulation of loaded deck sandwich panel and deck–bulkhead assembly structures

Zhongyang Qian, Frank Abdi and Ayman Mosallam

The paper assesses the validity of analytical methods in the fire simulation and structural evaluation of Naval Bulkhead and sandwich panel structures.

4. Nanocomposites

A method of visualization of inorganic nanoparticles dispersion in nanocomposites

S. Lingaiah, R. Sadler, C. Ibeh and K. Shivakumar

The paper demonstrated that the plasma-etch followed by scanning electron microscopy is a viable approach for visualizing the inorganic nanoparticles in polymer nanocomposites.

Bending buckling of single-walled carbon nanotubes by atomic-scale finite element

X. Guo, A.Y.T. Leung, X.Q. He, X.C. Zhang, H. Jiang and Y. Huang

This paper is the first attempt to employ the atomic-scale finite element method to study bending buckling of single-walled carbon nanotubes. It emphasizes their strain energy growth and morphological transformation, with a conclusion that the appearance of kinks reduces the slope of their strain energy curve and increases their flexibility.

Processing and modeling of conductive thermoplastic/carbon nanotube films for strain sensing

Giang T. Pham, Young-Bin Park, Zhiyong Liang, Chuck Zhang and Ben Wang

Pham et al. present the fabrication, modeling, and characterization of thermoplastic/carbon nanotube composite systems as high-performance, cost-effective strain sensing materials that allow versatility and tunable strain sensitivity.

5. Non destructive evaluation

Neural network based nondestructive evaluation of sandwich composites

Frederick Just-Agosto[1], David Serrano, Basir Shafiq and Andres Cecchini

[1] Box 9044, tel.: 787 832 4040x2546; fax: 7878 265 3817; e-mail address: fjust@me.uprm.edu.

It has been shown that a neural network trained with only partial and diverse damage detection signatures is capable of discerning damage in sandwich composites even when the situation presented does not match that of the training data.

Reliable low-cost NDE of composite marine sandwich structures

Emmanuel Ayorinde, Ronald Gibson, Shridhar Kulkarni, Feizhong Deng, Hassan Mahfuz, Sadikul Islam and Shaikh Jeelani

Efficient elastic identification and NDE methods were developed for marine composites, and minute nano-augmentation shown to significantly affect their properties and NDE responses.

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