Composites Manufacturing & Simulation Center

THE NEXT STEP IN COMPOSITES MANUFACTURING

The Composites Manufacturing & Simulation Center is driving composites manufacturing into the future by furthering the development and use of composites simulation. We all know current trial-and-error techniques are time-consuming and costly, limiting application of these materials. The CMSC is helping to solve this problem by developing a comprehensive set of simulation tools to model composite structures from manufacturing through retirement. In addition, state-of-the-art manufacturing and characterization facilities provide a one-stop-shop for composites design, manufacturing, prototyping, and model validation. Additionally, the CMSC is dedicated to training engineers across the entire composites community in composites manufacturing and simulation.

GREAT PEOPLE

The CMSC employs a wide range of highly qualified, full-time staff, including faculty, graduate and undergraduate research assistants and full-time research engineers. The faculty represent well over a century of experience in composites manufacturing, characterizing and simulation, including multi-scale modeling from atomistics to macro-scale. Faculty from Purdue Schools and Departments residing in IMI include Aeronautics and Astronautics, Chemical Engineering, Materials Engineering, Aviation Technology and Computer Graphics Technology.

GREAT FACILITIES

The CMSC occupies 32,000 ft^2 in the Indiana Manufacturing Institute, a building located in the Purdue Research Park and completed in 2016. Over 13,000 ft^2 are dedicated to composites manufacturing and testing in a lab space that closely mirrors actual processes for aerospace and automotive manufacturing. Currently, this includes the full range of aerospace manufacturing including automated ply cutting, autoclave and oven curing, and CNC tool fabrication. The CMSC has added vehicle manufacturing capabilities with high-pressure resin transfer modeling, laminate stamping, injection over-molding and composites additive manufacturing.

INDUSTRY INVOLVEMENT

The CMSC is a bridge between the academic and industrial communities, connecting the global composites industry and Indiana manufacturing to Purdue University. The CMSC research is driven by industry needs and grounded in academic rigor. Global sponsors and partners include aerospace and automotive OEMs, Tier 1 and 2 suppliers, materials suppliers, wind turbine manufacturers, and commercial software providers. Located in the Purdue Research Park, the CMSC is the portal for industry to interact with the world-class Purdue team around composites design, manufacturing, modeling, and simulation.

UNIQUENESS

The CMSC is dedicated to the future of composites manufacturing, including the promises of additive manufacturing. Sitting side-by-side is a team with capabilities spanning manufacturing, modeling and simulation, performance prediction, characterization, experimental validation, design, and prototyping, including rapid fabrication of composites tooling. With this full complement of capabilities, the CMSC is the locus for composites design, manufacturing, and simulation.

CONTACT INFORMATION

Indiana Manufacturing Institute | 3957 N 100 W, Suite 100, West Lafayette, IN 47906 | **purdue.edu/cmsc**

BUILDING THE COMPOSITES COMMUNITY

Purdue's **cdmHUB** is a collaborative web interface platform for hosting and evaluating available composites simulation tools, and for educating people in the use of those tools to:

- Advance composite materials design and manufacturing.
- Certify product performance.
- Simulate manufacturing processes.
- Accelerate development of the composite simulation talent-base.

cdmHUB's robust browser-based platform shares data and simulation tool developments in real-time while allowing continuous direct interaction with the composites community in a secure environment.

CDMHUB GOALS

- Advance the certification of composite products by analysis validated by experiments.
- Educate the current and future generations of engineers in the use of composite analysis tools.
- Evaluate composites simulation tools to determine functionality, compatibility and maturity.
- Develop a comprehensive set of simulation tools that connect composites from their birth in manufacturing to their lifetime prediction and accelerate the rate of development by an order of magnitude.
- Work with industry, academia and government to put these tools in the hands of engineers who will design future products that require the performance characteristics composite materials offer.

COMPOSITE PRODUCT CERTIFICATION

The body of knowledge developed by the National Nuclear Security Administration in Uncertainty Quantification (UQ) can be transferred to the composites field to guide the development of new product certification paradigms, including certification of simulation tools, based on prediction of product manufacture and performance variability.

REVOLUTION IN COMPOSITES DESIGN & MANUFACTURING

Simulation can provide the foundation for a revolution in composites design and manufacturing. The goal of certifying product manufacturing and performance by simulation is clearly within reach. The development of simulation codes that uniquely describe the phenomena involved in advanced materials manufacturing and performance will provide the building blocks for the construction of an integrated simulation suite to meet these needs.

EDUCATE THE TALENT-BASE OF USERS

Journal of Composites Simulation

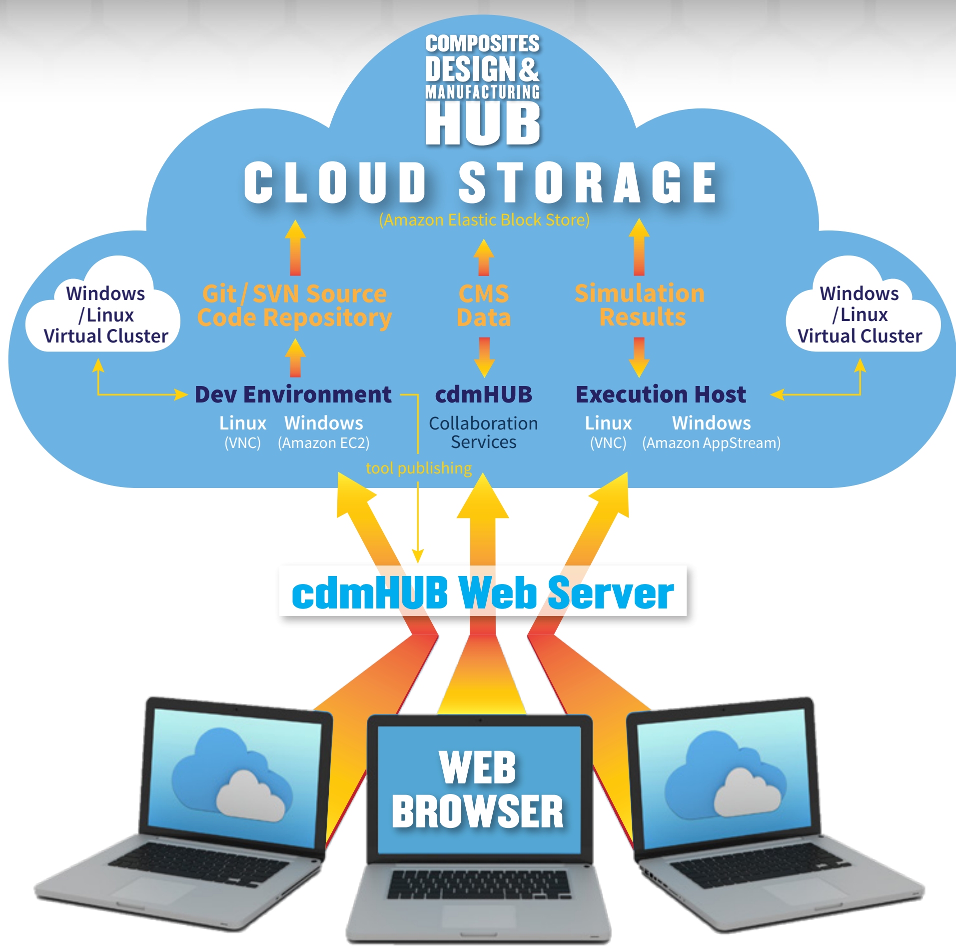
- Online journal of engineering and scientific papers describing composites simulation
- Archival journal review standards and knowledge codification
- "Active" equations, links to simulation codes and databases
- Author impact enhancement
- Education and evaluation of tools
- Composites Simulation Challenges announcements and results

CONTACT INFORMATION

Wenbin Yu, Director of cdmHUB | wenbinyu@purdue.edu | 765-494-5142 | **cdmhub.org**

Our Mission

Convene the composites community to advance certification by analysis through hosting and evaluating existing and emerging simulation tools.



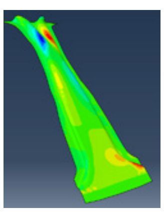
USERS

Researchers | Engineers | Manufacturers | Educators

Composites Design Studio

In the Composites Design Studio, we utilize cutting-edge computer aided design software to deliver composite design solutions. This is coupled with our co-located 10,000 ft^2 lab space where we turn our designs into reality with state of the art fiber reinforced composite manufacturing capabilities. We utilize advanced additive manufacturing technology to create prototype designs and tooling to make composite parts with High Pressure Resin Transfer Molding, Compression Molding, and Hybrid Injection Molding.

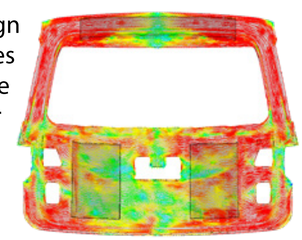
ANALYZE



The Composites Virtual Factory HUB (cvfhub.org) hosts the leading commercial software tools for simulating the manufacturing and performance of composite components. The ability to predict the performance of a composite part is only as good as the ability to accurately model the microstructure of a manufactured part. Detailed understanding of the microstructure of the composite leads to better prediction of the structural performance of the components. We analyze parts for stiffness, strength, vibration, and crash performance using industry standard software packages. The characterization lab in the Indiana Manufacturing Institute is utilized throughout this process to characterize the material inputs required for accurate simulations and to validate our results.

OPTIMIZE

Accurate simulation of the manufacturing and performance of composites is only the beginning of the design process. Through the use of the computing resources and rapid prototyping tools available in the Composites Design Studio, we offer industry partners the capability to rapidly iterate on designs and optimize the entire manufacturing process to yield the high performing parts that minimize cost. This holistic methodology for optimization allows us to anticipate challenges with different design approaches and offer solutions which may not be obvious at first sight, or with traditional analysis methods.



REVOLUTIONIZE

The objective of the Composites Design Studio is three-fold:

1. To offer a one-of-a-kind, industry-focused, hands-on experience for graduate students at Purdue, the preeminent university for composites design education.
2. To meet the needs of our industry partners with cutting-edge design processes using state-of-the-art computer analysis methods.
3. To equip the next generation of composite design experts for careers in a growing number of industries which require experience in the design and manufacturing of composite materials.

Who should apply? Non-thesis Masters students with an interest in the design, modeling, and simulation of composite materials, with expected graduation of December 2018 or later.

Preferred Majors: Civil Engineering, Mechanical Engineering, Aeronautics and Astronautics Engineering.

R. Byron Pipes

Distinguished Professor » bpipes@purdue.edu » 765.494.5767

Composites Manufacturing & Simulation Center

BIO

Dr. R. Byron Pipes was elected to the National Academy of Engineering in 1987 in recognition of his development of an exemplary model for relationships between corporate, academic and government sectors to foster research and education in the field of composite materials. As co-founder and director of the Center for Composite Materials at the University of Delaware, he developed an industrial consortium of over forty corporate sponsors from the USA, Japan, Germany, France, Italy, United Kingdom, Belgium, Sweden and Finland. Today, almost 40 years after its founding, the University of Delaware Center is the largest and most successful of its kind in the United States. Research expenditures have exceeded $100 million. In 2013, Dr. Pipes developed the Composites Design and Manufacturing HUB (**cdmHUB**) to meet the simulation needs of the growing composites industry. To date, the **cdmHUB** is supported by five corporate sponsors (Boeing, Rolls Royce, Cytec, Dassault Systemes and Henkel) as well as DARPA. His most recent research programs focus on the development of composites manufacturing with emphasis on additive manufacturing. He currently leads the Indiana Center of Excellence of the DOE Institute for Advanced Composites Manufacturing Innovation (IACMI) as Director of the Design Modeling and Simulation Technology Area.

He is the Executive Director of the Composites Manufacturing & Simulation Center (CMSC) housed in the Indiana Manufacturing Institute in the Purdue Research Park. He has active programs in the study of the advanced manufacturing science for composite materials.

APPOINTMENTS

- Executive Director of the Composites Manufacturing Simulation Center of Purdue University, 2015–present.
- Director of the Design and Simulation technology Area of the Institute for Advanced Composites Manufacturing, 2015–present.
- Director of the Composites Design and Manufacturing HUB, 2012–present.
- John Bray Distinguished Professor of Engineering in the Schools of Aeronautics and Astronautics, Chemical Engineering and Materials Engineering at Purdue University, 2004–present.
- Goodyear Professor of Polymer Engineering, University of Akron, 2001–04.
- Distinguished Visiting Professor, College of William and Mary, 1999–2001.
- President of Rensselaer Polytechnic Institute, 1993–95.
- Provost of the University of Delaware, 1991–1993.
- Dean of the College of Engineering, University of Delaware, 1985–91.
- Robert L. Spencer Professor of Engineering, University of Delaware, 1986–93.
- Director of the Center for Composite Materials, University of Delaware, 1977–85.

HONORS AND AWARDS

- National Academy of Engineering (1987)
- Royal Society of Engineering Sciences of Sweden (1995)
- Gustus L. Larson Award of Pi Tau Sigma (1986)
- Chaire Francqui, Distinguished Faculty Scholar Award in Belgium (1985)
- Fellow rank in ASC, ASME and SAMPE

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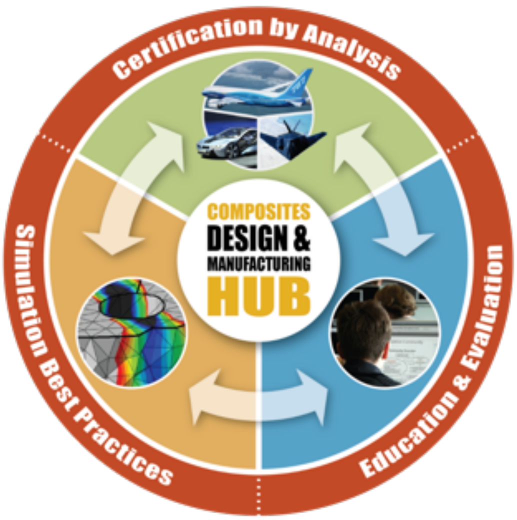

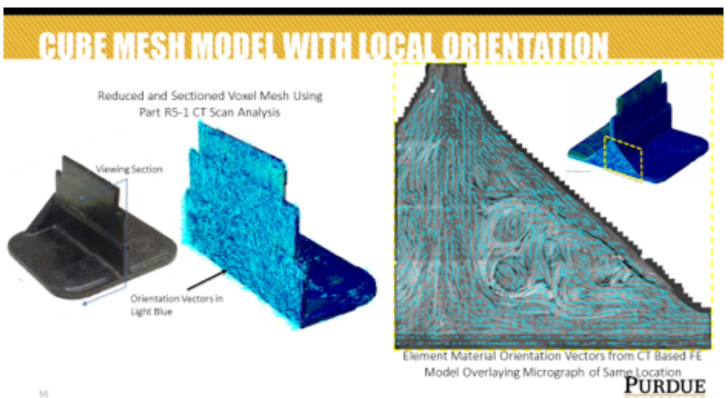

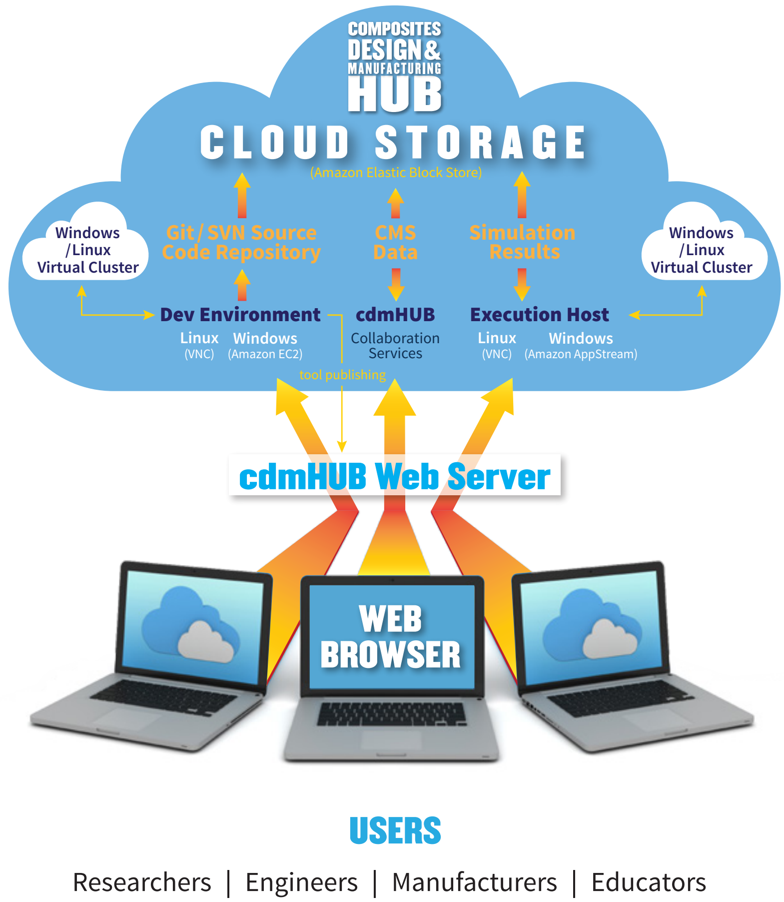

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Jan-Anders Mansson

Distinguished Professor » jmansson@purdue.edu » 765.494.8244

Composites Manufacturing & Simulation Center

BIO

Following five years in Industry as CTO Mansson moved in 1985 to an academic position at the University of Washington, Seattle. In 1990, he joined the Ecole Polytechnique Fédérale de Lausanne (EPFL) as Professor and Director of a newly created chair in Polymer and Composite Technology (LTC) at the Institute of Materials. His research interests are primarily in Composite manufacturing, covering topics such as:

- Processes & Materials for “High-Volume” Composites
- Hybrid Molding for Complex Shape Molding
- Functional Material-Forms
- Technical Cost Modeling & Implementation Strategies

Besides his research, Prof. Manson was during a period Vice-president at the Ecole Polytechnique Fédérale de Lausanne, focusing on Innovation and Technology Transfer. Since 2008, Prof. Mansson is besides his University engagement, President of the International Academy of Sports Science and Technology, AISTS, an International Olympic Committee (IOC) co-founded organization linking Academic Institutions in Sport Management and Technology.

Prof. Mansson is the founder of the composite companies, EELCEE Ltd. and QEESTAR Co. Ltd. (JV) active in the field of High-Volume Composites and Additive Manufacturing. The two companies have today its main operation in Korea and Europe.

CURRENT RESEARCH FOCUS

The research is focused on novel cost-effective materials and manufacturing methods as well as unique additional functionalities, beyond the classical performance characteristics of composite materials. The research involved both process and material specific topics but most importantly the interaction between material and process specific characteristics. In addition are scaling strategies for implementation in industrial context emphasized. The research partners are in the Automotive, Aerospace, Chemical, Medical and Sport industries.

MAIN RESEARCH THEMES

EFFICIENT MASS PRODUCTION OF COMPOSITES

- Process integration
- High-rate processes
- Complex shape forming

INCREASED FUNCTIONALITY OF COMPOSITES

- Material-form hybridization
- Integrated Sensing & Monitoring
- Adaptive composites

COST-EFFECTIVE HIGH-VOLUME COMPOSITE MANUFACTURING

- Tailored material-form designs
- Material/Process hybridization
- Adaptive manufacturing lines
- Technical Cost Modeling
- Life Cycle Engineering (LCA & LCC)

RECENT PUBLICATIONS

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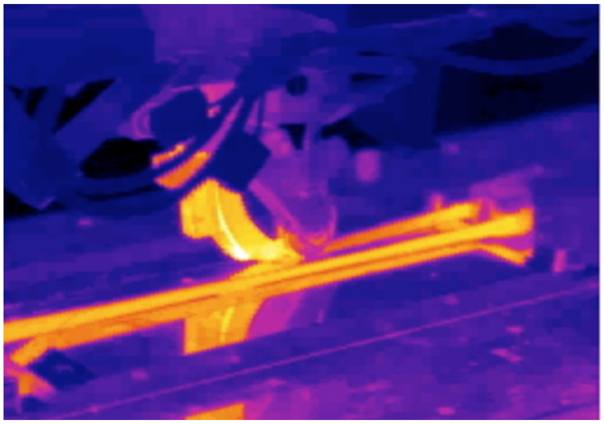

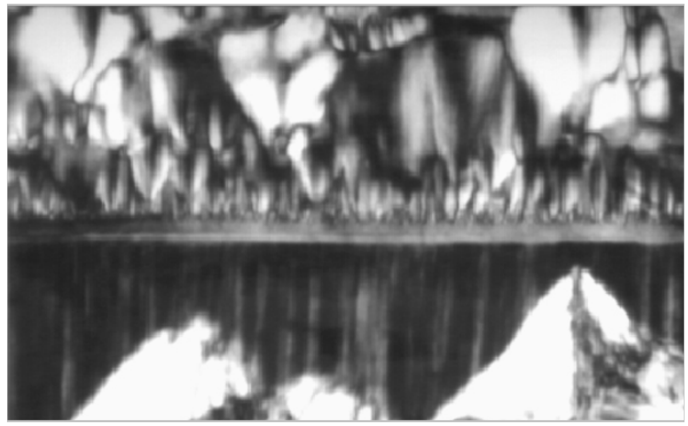

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RECENT PATENTS AND PATENT APPLICATIONS

- Self-monitoring composite vessel for high pressure media
- High pressure media storage vessel comprises a wall made of a layer with barrier and piezoelectric properties and has self-sensing capability
- Dual cure compositions, related hybrid nanocomposite materials and dual cure process for producing same
- Electrochemical cell (Collecteurs de courant ultra-flexibles et imperméables)
- Structures with Shear thickening fluids
- Composite Hydrogels
- Biocompatible multi-layered structure comprising foam layers and a functional interface

Johnathan Goodsell

Research Assistant Professor » jgoodsell@purdue.edu » 765.496.0562

Composites Manufacturing & Simulation Center

purdue.edu/cmsc

BIO

Dr. Goodsell's research interests are in the field of validation of models for composites manufacturing and performance. Since completion of his PhD in 2013 with Professor R. Byron Pipes, Dr. Goodsell has served as a Visiting Assistant Professor and Research Assistant Professor of Aeronautics and Astronautics at Purdue University.

In his role as Director of Validation in the Composites Manufacturing and Simulation Center, Dr Goodsell is establishing automotive manufacturing capability to complement the existing aerospace manufacturing facilities. Responsibilities for validation efforts include design and execution of validation experiments and simulations for composites manufacturing processes, including high-pressure resin transfer molding, laminate stamping, injection overmolding and composites 3D printing. As Assistant Director of the Composites Virtual Factory HUB (**cvfHUB**) he is planning and coordinating the integration of commercial simulation codes to model composites manufacturing processes. As a member of the CMSC leadership team, he plans and coordinates efforts among 5 staff engineers and has responsibility for the manufacturing and testing laboratories. Current efforts are centered in the 5th NNMI, the Institute for Advanced Composites Manufacturing Innovation (IACMI), a multi-state, multi-institution $260M+ program with $70M DOE funding.

Dr. Goodsell has also helped launch and lead the **Composites Design and Manufacturing HUB**, which was officially recognized as a Purdue Center in June 2014, and is currently supported by 5 industrial partners, including aerospace OEMs, materials suppliers and commercial simulation tool providers. The mission of the Composites Design and Manufacturing HUB (**cdmHUB.org**) is to accelerate the certification of aerospace products by analysis by advancing the number and "best practice use" of simulation tools for composite materials. He has become familiar with the functionalities and providers of the major commercial and academic simulation tools relative to composites manufacturing and performance and is leading efforts in education of the user community. He has assisted in developing and promoting a "Simulation Tool Taxonomy" with expert evaluations of commercial simulation tools. With Director R. Byron Pipes and Associate Director Wenbin Yu, Dr. Goodsell has planned and executed multiple industrial sponsor's meetings and composites education workshops with participants from industry, government and academia. In collaboration with industry, he and Professor Wenbin Yu developed the "Micromechanics Simulation Challenge," launched in January 2015. He has taken the cdmHUB to the world, promoting at major composites conferences and at workshops and industry gatherings. He is also guiding students in developing "Composites Apps" to codify knowledge in the form of simulation tools. He is the author, co-author or adviser of over a dozen simulation tools on **cdmHUB.org.**

RESEARCH INTERESTS:

- Composites manufacturing, testing and analysis
- Validation of composites models
- Verification, validation and uncertainty quantification

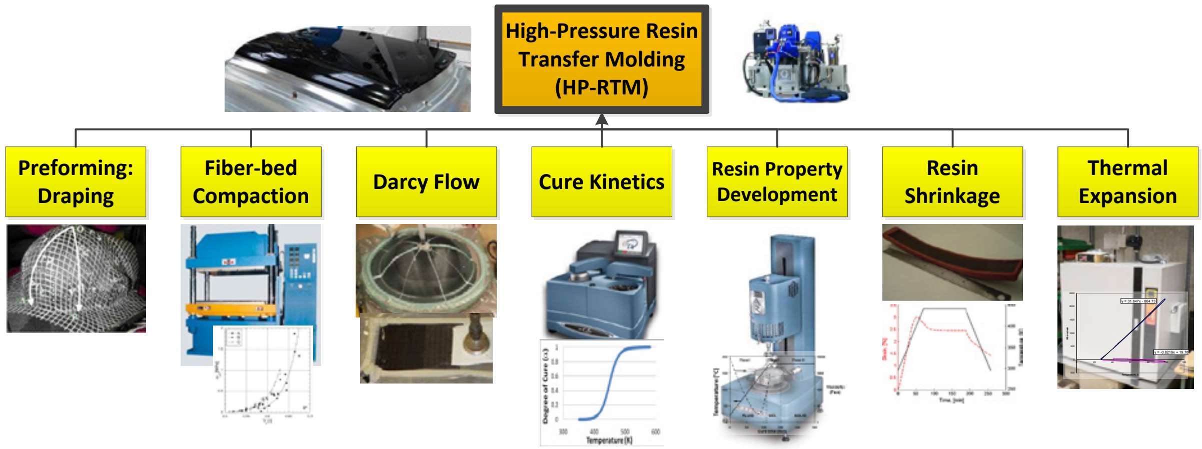

Figure 1. Integration of physical phenomenon in High-Pressure Resin Transfer Molding

PUBLICATIONS

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Goodsell, J.; Pagano, N.J.; Kravchenko, O.; Pipes, R.B., "Interlaminar Stresses in Composite Laminates Subjected to Anticlastic Bending Deformation," Journal of Applied Mechanics, Vol. 80, No. 4, (2013).

Mendoza Jasso, A.J.; Goodsell, J.E.; Pipes, R.B.; Koslowski, M., "Validation of Strain Invariant Failure Analysis in an Open Hole Off-Axis Specimen," Journal of Materials, Vol. 63, No. 9, pp. 43-48 (2011).

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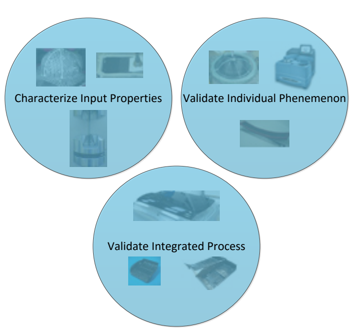

Figure 2. Experimental Validation Efforts

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Wenbin Yu

Professor » wenbinyu@purdue.edu » 765.494.5142

CMSC
Composites Manufacturing & Simulation Center

BIO

Dr. Wenbin Yu is a Professor in the School of Aeronautics and Astronautics at Purdue University. He also serves as the Director for the Composites Design and Manufacturing HUB (**cdmHUB**) and as the Associate Director for the Composites Virtual Factory HUB (**cvfHUB**), as well as the CTO for **AnalySwift LLC**. His expertise is in micromechanics and structural mechanics with applications to composite/smart materials. He has developed seven computer codes which are being used in government labs, universities, research institutes and companies. His research has been funded by both federal agencies and private industry. He discovered the Mechanics of Structure Genome (MSG) which provides a unified approach for modeling of advanced materials and structures. MSG is implemented in SwiftComp, a general-purpose multiscale constitutive modeling code recently commercialized by Purdue Research Foundation. He is an ASME Fellow and AIAA Associate Fellow.

RESEARCH INTERESTS

- Multiscale Modeling
- Structural Mechanics
- Micromechanics
- Computational Mechanics
- Multiphysics Modeling
- Composites Processing Modeling
- Composites/Smart Materials/Structures

CURRENT RESEARCH FOCUS

Mechanics of Structure Genome: A major research focus of Prof. Yu's group is to establish the newly discovered mechanics of structure genome (MSG) as a new paradigm of composites modeling for possible unification of structural mechanics and micromechanics and provided a novel approach for multiscale structural modeling. MSG not only formulates structural mechanics as a special application of micromechanics, but also provides a rigorous approach to elegantly handle complex buildup structures with heterogeneities from the micro scale all the way to macroscopic scale. This unified formulation has been implemented into a general-purpose multiscale modeling code called SwiftComp which is recently commercialized by Purdue Research Foundation and licensed by AnalySwift. This code can be used as a standalone code for virtual testing of composites or as a plugin module to power conventional FEA codes with efficient high-fidelity composites modeling capabilities. SwiftComp takes a block of material to compute the constitutive models for the macroscopic structural model including beam/plate/shell and 3D structural model. SwiftComp is freely accessible in the cloud at **cdmhub.org/resources/scstandard**.

PUBLICATIONS

Wang, Q. and Yu, W.: "A Variational Asymptotic Approach for Thermoelastic Analysis of Composite Beams," Advances in Aircraft and Spacecraft Science, vol. 1, 2014, pp. 93-123.

Lee, C.-Y.; Yu, W.; and Hodges, D. H.: "A Refined Modeling of Composite Plates with In-Plane Heterogeneity," Journal of Applied Mathematics and Mechanics, vol. 94, 2014, pp. 85-100.

Pollayi, H. and Yu, W.: "Modeling matrix cracking in composite rotor blades within VABS framework," Composite Structures, vol. 110, 2014, pp. 62-76.

Ye, Z.; Berdichevsky, V.; and Yu, W.: "An Equivalent Plate Modeling of Corrugated Structures," International Journal of Solids and Structures, vol. 51, 2014, pp. 2073-2083.

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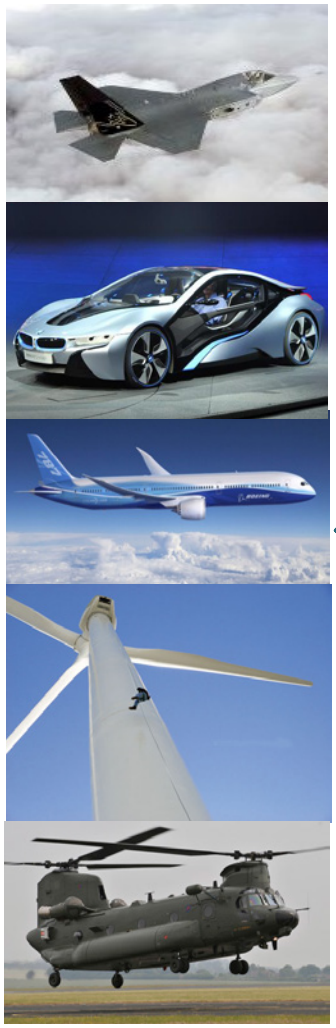


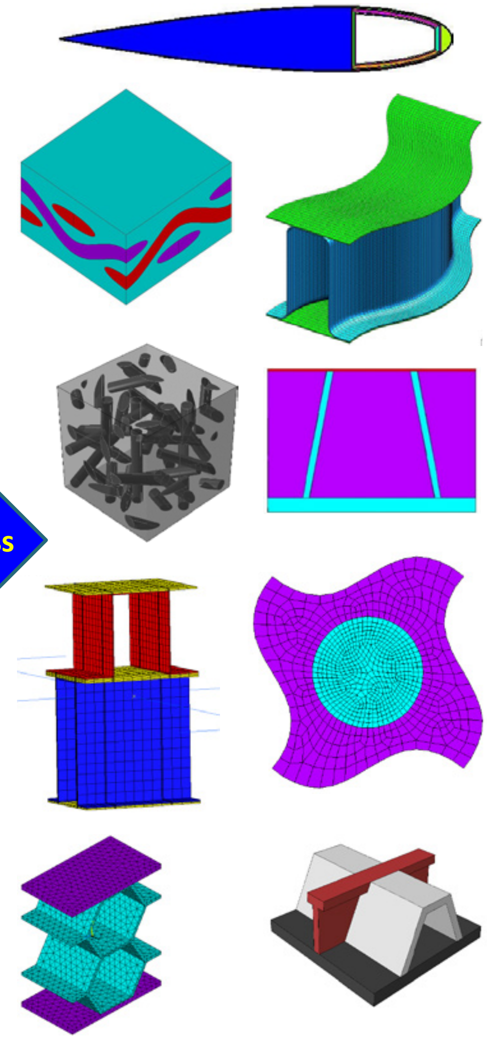
Right Results
Right Away

SwiftComp™

A Purdue Technology

Principle of Minimum Information Loss

- **Virtual testing of materials**
  - Mechanical properties
  - Multifunctional properties
- **Multiscale modeling of structures**
  - Composite structures
  - Stiffened structures
  - Build-up structures



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Liu, X.; Rouf, K.; Peng, B.; and Yu, W.: "Two-Step Homogenization of Textile Composites Using Mechanics of Structure Genome," Composite Structures, vol. 171, 2017, pp. 252-262.

Liu, X.; Rouf, K.; Peng, B.; and Yu, W.: "Two-Step Homogenization of Textile Composites Using Mechanics of Structure Genome," Composite Structures, vol. 171, 2017, pp. 252-262.

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Zhang, L.; Gao, Z.; and Yu, W.: "A string-based cohesive zone model for interlaminar delamination," Engineering Fracture Mechanics, vol. 180, 2017, pp. 1-22.

Michael J. Bogdanor

Director, Composites Design Studio » bogdanor@purdue.edu » 765.496.6484

Composites Manufacturing & Simulation Center

BIO

Originally from Columbia, MD, Mike received his B.S. Civil Engineering from Villanova University in 2009, where he also earned a Business minor and was a member of the Men's Lacrosse team. Upon graduation, he was employed at Bechtel Power Corporation performing structural steel design for the Ivanpah Solar Electric Generating System. After completion of Ivanpah's design, Mike left to pursue his PhD in Civil Engineering, which he received from Vanderbilt University in 2015. At Vanderbilt, he studied under Dr. Caglar Oskay in the Multiscale Computation Mechanics Laboratory where his primary research focus was the failure prediction of laminated composites using reduced order multiscale homogenization. He joined the CMSC at Purdue in January 2016 and lives in West Lafayette, IN with his wife, Merissa and daughter, Mikayla. He enjoys woodworking, lacrosse, and playing drums in the band at his church.

RESEARCH INTERESTS

- Multiscale modeling – Using reduced order computational homogenization techniques to accurately and efficiently predict the structural response of large systems from the local behavior of their constituents.
- Failure prediction of composite materials – Utilizing multiscale modeling techniques to predict the failure of composite materials under static, dynamic, and cyclic loading. Predicting the accumulation in the heterogeneous microstructure to understand the growth and interaction of structural scale failure mechanisms.
- Uncertainty quantification – Calibrating the behavior of complex systems in the presence of sparse and incomplete data. Utilizing statistical analysis methods and high performance computing to design robust and reliable systems that account for uncertainty from multiple sources.
- Design and optimization automation – Formalizing end-to-end simulation approaches from manufacturing to performance to facility rapid design iteration and achieve optimal designs while significantly reducing the need for physical iteration of prototype designs.

PUBLICATIONS

M. J. Bogdanor, and C. Oskay. "Prediction of progressive fatigue damage and failure behavior of IM7/977-3 composites using the reduced-order multiple space-time homogenization approach." Journal of Composite Materials, Aug 26, 2016.

M. J. Bogdanor, and C. Oskay. "Prediction of Progressive Damage and Strength of IM7/977-3 Composites using the Eigendeformation Based Homogenization Approach: Static Loading." Journal of Composite Materials, May 25, 2016.

M. J. Bogdanor, C. Oskay, and S. B. Clay, "Multiscale Modeling of Failure in Composites under Model Parameter Uncertainty," Computational Mechanics, 56:389-404, 2015.

M. J. Bogdanor, S. Mahadevan and C. Oskay, "Uncertainty Quantification in Damage Model-ing of Heterogeneous Materials," International Journal for Multiscale Computational Engineering, 11(3):289-307, 2013

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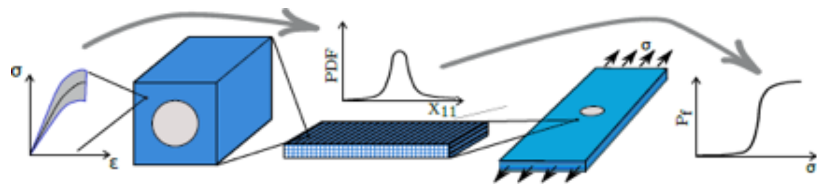

Figure 1. Multiple scales of uncertainty in a laminated composites structure from natural variability in constituent materials to laminate strength distributions

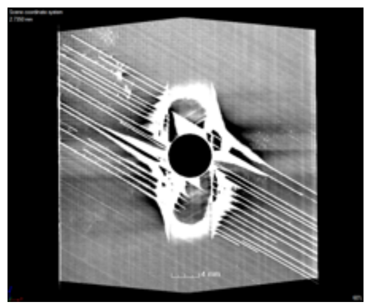

Figure 2. Interacting failure mechanisms in a [60,0,-60]3s coupon still able to carry significant load in the vertical direction

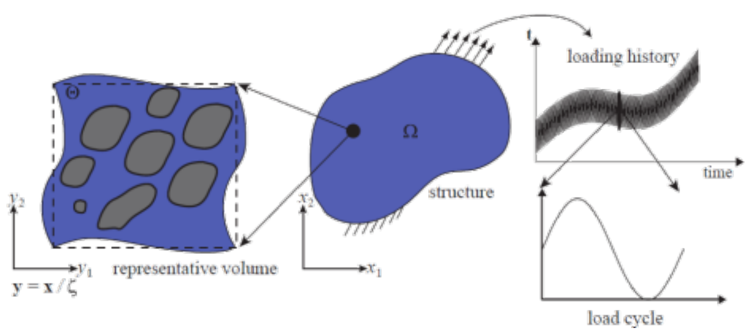

Figure 3. Multi-spatial/multi-temporal modeling framework.

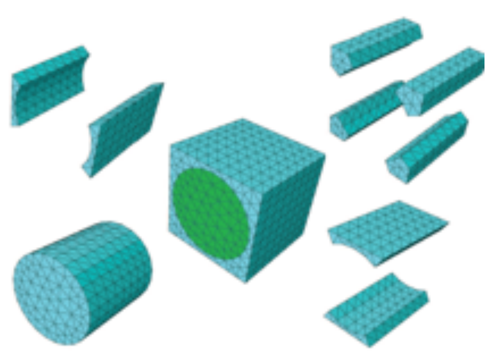

Figure 4. Graphical representation of a reduced order multiscale model used to predict the failure evolution of multiple local failure mechanisms in laminated composites

Rebecca Cutting

Validation Engineer » rcutting@purdue.edu » 765.496.3822

Composites Manufacturing & Simulation Center

WORK EXPERIENCE

Validation Engineer, Composites Manufacturing and Simulation Center

Purdue University, West Lafayette, IN (August 2016–present)

Currently researching noise and vibration analysis methods for automotive industry and how they can be applied to parts made of composite materials. Primarily interested in structural dynamic test and analysis correlation, and how composite manufacturing methods and materials affect dynamic performance and properties. Responsible for validating commercial software packages using industry standard test methods.

Structural Dynamics Test Engineer

The Boeing Company Structural Dynamics Lab, Seattle, WA (May 2013-August 2016)

Worked as a lab test intern the summers of 2013 and 2014; full time employee starting in June 2015. Planned, coordinated, and executed a variety of structural dynamic tests including ground vibration tests, flutter tests, operational modal analysis tests, and impact tests. Specialized in flutter testing for the structural dynamics lab, responsible for preparation of data acquisition and analysis systems in flutter testing. On team to convert to digital data acquisition in telemetry room for flutter flight testing. Gained significant experience with high speed dynamic data acquisition hardware, large scale test setups, and modal parameter estimation. Notable projects include 737MAX flutter testing, KC-46A airplane flutter testing, KC-46A boom flutter testing, 747-8I flutter testing, 737MAX ground vibration test, and P-8 Poseidon full rate production ground vibration test.

Graduate Research Assistant

Purdue University, West Lafayette, IN (August 2013–May 2015)

Researched the effect of microstructure variability in discontinuous fiber parts on dynamic properties. Modeled compression molded parts made with thermoplastic prepreg chopped into ½″ square platelets. Applied micromechanical material models to the complex and variable microstructure of theoretical parts to predict range of dynamic properties. Used modal assurance criterion (MAC) and coordinate modal assurance criterion (COMAC) to evaluate changes in dynamic properties from microstructure variability.

Engineering Co-op Student

ATA Engineering Inc., San Diego, CA (August 2009–August 2012)

Completed a 5-term co-op with ATA Engineering. Learned advanced finite element modeling and simulation techniques. Gained experience in modal analysis, stress analysis, and response simulation in a variety of commercial FEA codes. Focused on dynamic simulations for component and aerospace systems. Learned basics of statistical energy analysis and implemented knowledge in launch analyses for spacecraft using VA One.

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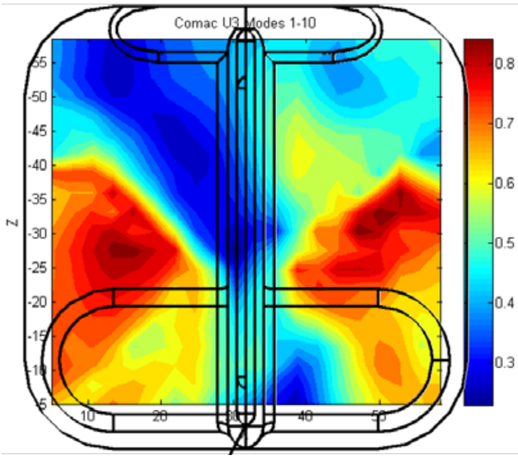


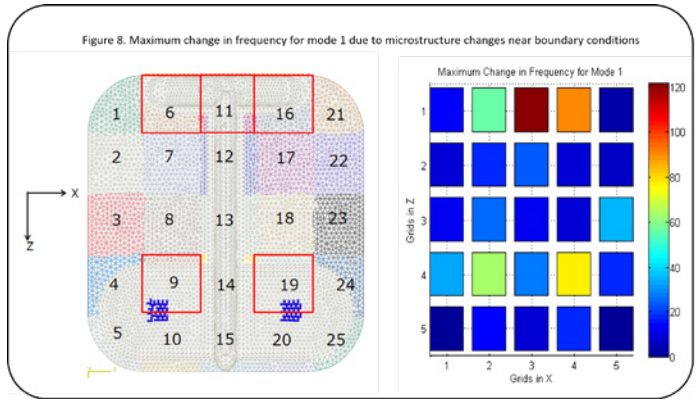
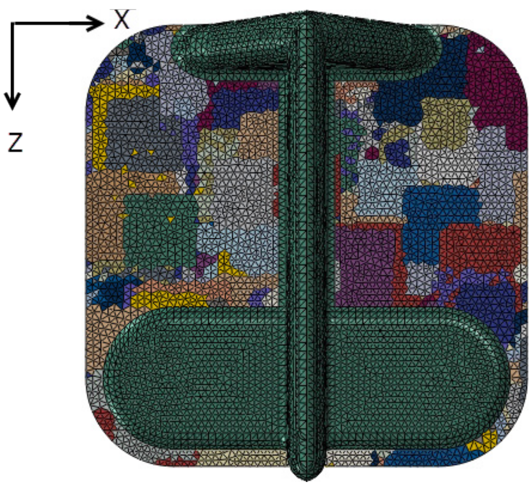


Figure 8. Maximum change in frequency for mode 1 due to microstructure changes near boundary conditions



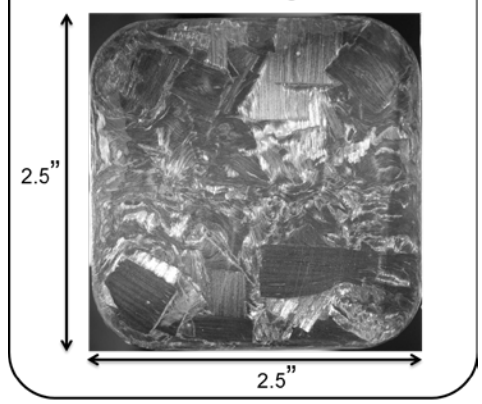


Figure 4. Micrograph of part with distinct platelets after molding

TEACHING EXPERIENCE

Graduate Teaching Assistant

Purdue University, West Lafayette, IN (August 2013-May 2015)

Teaching assistant for Mechanics of Materials, Structural Analysis I, Characterization of Advanced Composite Materials, and Mechanics of Composites. Created quizzes, homework problems, and homework solutions for undergraduate structures classes. Lectured on topics such as structural dynamics, superposition of beam solutions, and shear flow. Instructed students on use and purpose of lab equipment for testing of composites.

PUBLICATIONS

Cutting, Rebecca. (2015). Considerations for Nondestructive Evaluation of Discontinuous Fiber Composites Using Dynamic Analysis. (Master’s thesis). Retrieved from ProQuest LLC.

RESEARCH INTERESTS

- Structural dynamic testing and analysis techniques for composite materials
- Structural dynamic test and analysis correlation
- Dynamic properties of variable microstructure parts

SKILLS

Computer Programming: Java, Matlab, Fortran, C, LaTEX, Python, Bash, Visual Basic

Computer Graphics and Analysis Software: CATIA, NX, VAOne, FEMAP, I-deas, Abaqus, NASTRAN, X-Modal

Familiar Hardware: VTI CMX chassis series with EMX series cards, VTI PMX09 integrated data acquisition controller and computer, SLICE Micro and SLICE PRO Data Acquisition Systems, VXI bus with VTI 143X series cards, Polytec PSV-400 Scanning Laser Vibrometer

Ben Denos

Postdoctoral Researcher » bdenos@purdue.edu

Composites Manufacturing & Simulation Center

BIO

Originally from Mission Viejo, CA, Ben received his B.S. Mechanical Engineering from Brigham Young University in 2011. Ben worked as an undergraduate research assistant for General Motor's International P.A.C.E. Formula 1 Project performing design and assembly of a formula 1 style race car with a CFRP monocoque, specifically assigned to rear wing design. While attending and after graduating from BYU he worked as an intern and then associate engineer at GeoStrut in Lindon Utah designing tooling, developing inspection methods, and analyzing lab and field test data for filament wound, open-lattice CFRP poles and towers. Ben left GeoStrut to work on his Master's Degree in Aeronautical and Astronautical Engineering Structures and Materials at Purdue University from 2012-2014 focusing on characterization of fiber orientation in compression molded "chopped" prepreg tape composites using computed tomography scans of entire parts and validation via optical microscopy. He continued this work under advisor, Dr. R. Byron Pipes, to improve CT scan fiber orientation analysis and data mapping methods, and received his Ph.D. in August 2017. Ben is now a Post-Doctoral Research Assistant in the Composites Manufacturing & Simulation Center.

CURRENT RESEARCH FOCUS

- Inspection of chopped fiber material systems via CT scan image analysis and optical microscopy to accurately characterize micro- and meso-structure.
- Mapping of microstructural data to finite element meshes for "digital twin" simulations.
- Digital image correlation for full field strain comparison of highly heterogeneous chopped composites for comparison with finite element simulation strain fields.

PUBLICATIONS

Denos, Benjamin. CT Scan Analysis for the Characterization of Fiber Orientation in Long Discontinuous Fiber Composite Materials. (Master's Thesis). 2014.

Denos, Benjamin R., Pipes, R. Byron. Local Mean Fiber Orientation via Computer Assisted Tomography Analysis for Long Discontinuous Fiber Composites. 31st ASC Technical Conference and ASTM D30 Meeting, 2016.

Denos, Benjamin. Fiber Orientation Measurement in Platelet-Based Composites Via Computed Tomography Analysis. (PhD Dissertation). 2017.

RESEARCH FIGURES

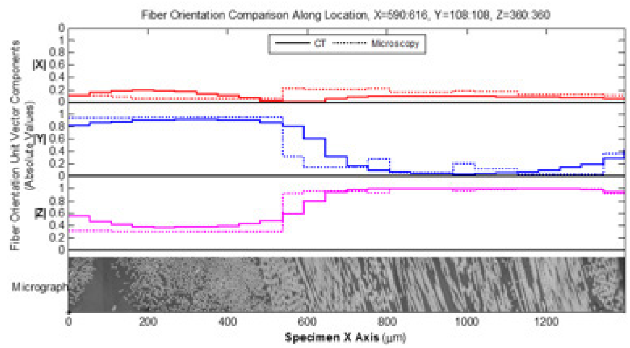


Figure 1. Visual Correlation of Microscopy and CT Data Fiber Orientation Components

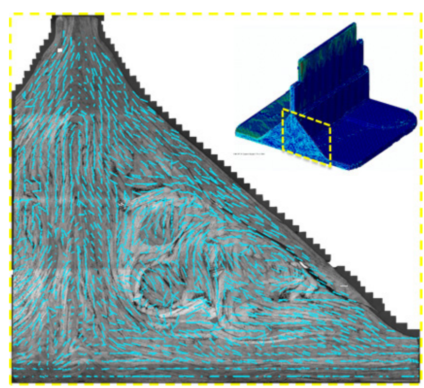


Figure 2 Element Material Orientation Vectors from CT Based FE Model Overlaying Micrograph of Same Location

purdue.edu/cmsc

Joshua Dustin

Senior Software Application Engineer » jdustin@purdue.edu » 765.494.5369

Composites Manufacturing & Simulation Center

Dr. Dustin holds a M.S.E. and Ph.D. from Purdue University's School of Aeronautics and Astronautics and a B.S. in Mechanical Engineering from Brigham Young University. He serves on the Materials Technical Committee for the AIAA concentrating primarily on ICME initiatives. He holds a US patent in the area of composite material testing and has multiple pending patent applications in addition to his conference proceedings and other technical publications.

PRIMARY RESEARCH INTERESTS

- Composite manufacture process modeling and manufacturing method development
- Mechanical test method design and development
- Analysis method validation

PATENTS

- J.J. Esposito, J.S. Dustin, US Patent #9464975, "Composite Test Specimen," (Oct 2016)

BIO

Dr. Dustin brings a pragmatic perspective on composite structure design, manufacture, analysis and test to the CMSC. His interest in composite materials grew from his love for skiing, biking, and watersports which he developed into a successful career in the aerospace industry. He has worked in a wide range of areas including:

- Development of automated vacuum bagging technologies for autoclave processing
- Adhesive bonding of metallic and composite structure
- Multi-scale modeling of composite materials
- Progressive failure analysis of composite structure via advanced non-linear FEA
- Mechanical and physical test method development
- Progressive failure analysis method development and validation
- Advanced non-destructive evaluation including in-situ techniques for identification of failure initiation and mapping failure propagation
- Composite design allowables including test selection, design and statistical data reduction on tape, fabric, braid, and carbon/glass hybrid material architectures

PUBLICATIONS AND PATENT APPLICATIONS

J.S. Dustin, J.J. Esposito, A.W. Baker, US Patent Application #14/326646, "Strength Testing of a Flatwise Material Coupon," (July 2014)

G. Freihofer, J. Dustin, H. Tat, A. Schulzgen, S. Raghavan. Stress and structural damage sensing piezospectroscopic coatings validated with digital image correlation. AIP Advances, (2015).

J.S. Dustin, "Stress and Strain Field Singularities, Micro-cracks, and Their Role in Failure Initiation at the Composite Laminate Free-Edge," Ph.D. Dissertation, Purdue University, (2012).

J. S. Dustin, R.B. Pipes. "Free-Edge Singularities Meet the Microstructure: Important Considerations", Composites Science & Technology, (2012).

A. Ritchey, J. Dustin, J. Gosse, R.B. Pipes. Self-Consistent Micromechanical Enhancement of Continuous Fiber Composites, Advances in Composite Materials, InTech (2011).

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J.S. Dustin, "Strength Predictions of Bonded Joints Using the Critical CTOA Criterion," Masters Thesis, Purdue University, (2009).

T. Boswell, J.S. Dustin, M.D. Ridges, C. Robinson, US Patent Application #US 20080083493 A1, "Reusable mechanical fastener and vacuum seal combination," (April 2006).

purdue.edu/cmsc

Sergey Kravchenko

Postdoctoral Researcher » skravche@purdue.edu

Composites Manufacturing & Simulation Center

purdue.edu/cmsc

BIO

Sergey received his B.S. in Aerospace Engineering in 2004 and M.S. in Aeronautical and Astronautical Engineering in 2006 from Zhukovskii National Aerospace University ("KhAI", Kharkiv, Ukraine). He worked for his Candidate of Technical Sciences degree in Mechanics of Deformable Bodies in 2006–2010 while being employed at KSAMC (Kharkiv State Aircraft Manufacturing Company, Ukraine) in 2007–2009 as an engineer at the department of forward and rear fuselage assembly for AN-140 and AN-72 airplanes. Sergey was teaching undergrad level classes (strength of materials, structural analysis) at the Department of Aircraft Strength at "KhAI" in the period of 2009–2012. He became a visiting researcher to Purdue in 2012 under Fulbright program and work with Dr. CT Sun. Sergey started his program at Purdue in 2014 under Dr. R Byron Pipes research group.

RESEARCH INTERESTS

Progressive failure analysis of composite systems compression molded from prepreg-based platelet compound.

PUBLICATIONS

OG Kravchenko, R Misiego, SG Kravchenko, RB Pipes, I Manas-Zloczower. "Modeling of hierarchical morphology of carbon nanotube bundles in polymer composites", Macromolecular Theory and Simulations 2016; 25(6): 524-532

OG Kravchenko, SG Kravchenko, CT Sun. "Thickness dependence of mode I interlaminar fracture toughness in carbon fiber thermosetting composite", Composite Structures 2017; 160: 538-546

OG Kravchenko, SG Kravchenko, RB Pipes. "Chemical and thermal shrinkage in thermosetting prepreg", Composites Part A 2016; 80: 72-81

OG Kravchenko, SG Kravchenko, A Casares, RB Pipes. "Digital image correlation measurement of resin chemical and thermal shrinkage", J Mater Sci 2015; 50: 5244-5252

SG Kravchenko, OG Kravchenko, LA Carlsson, RB Pipes. "Influence of through-thickness reinforcement aspect ratio on mode I delamination fracture resistance", Composite Structures 2015; 125: 13-22

OG Kravchenko, C Li, A Strachan, SG Kravchenko, RB Pipes. "Prediction of the chemical and thermal shrinkage in a thermoset polymer", Composites Part A 2014; 66: 35-43

SG Kravchenko, OG Kravchenko, CT Sun. "A two-parameter fracture mechanics model for fatigue crack growth in brittle materials", Engng Fract Mech 2014; 119: 132-147

SG Kravchenko, OG Kravchenko, M Wortmann, M Pietrek, P Horst, RB Pipes. "Composite toughness enhancement with interlaminar reinforcement", Composites Part A 2013; 54: 98-106

RESEARCH FIGURES

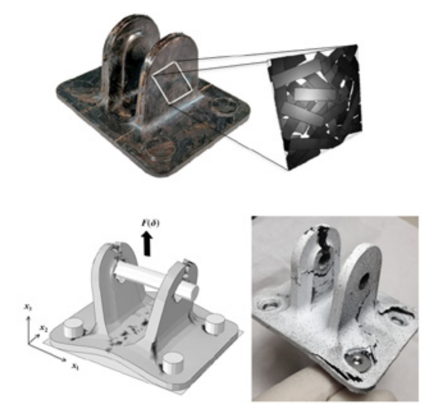

Figure 1: Simulated failure of a pin-bracket compression molded from a prepreg-based platelets

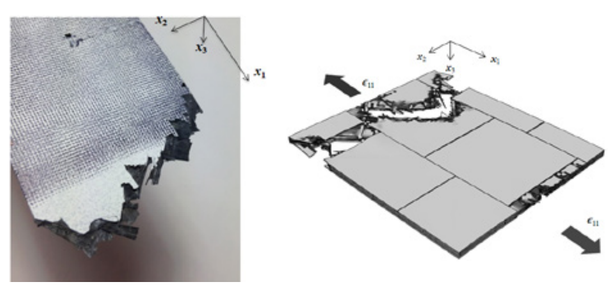

Figure 2: Failure prediction of a tensile bar made of staggered platelets

Brian L. Rohler

Director of Information Technology » brohler@purdue.edu » 765.494.2712

Composites Manufacturing & Simulation Center

purdue.edu/cmsc

BIO

Brian L. Rohler is the Director of Information Technology for the Institute of Advanced Composites Manufacturing Innovation (IACMI) at Purdue University located in the Indiana Manufacturing Institute building within the Purdue Research Park. IACMI, a DOE funded Manufacturing Innovation Institute led by the University of Tennessee, was awarded in 2015 and is focused on bringing cost competitive manufacturing of composite material components to automotive, wind, and gas storage applications. Purdue hosts the Manufacturing Design, Modeling, and Simulation Technology Area, one of five Technology Areas within IACMI.

Mr. Rohler's previous position was the Director of Information Technology for the Network for Earthquake Engineering Simulation (NEES), a National Science Foundation cooperative agreement. This $105M grant was the largest grant ever received at Purdue University. NEES's mission was to accelerate improvements in seismic design and performance by serving as an indispensable collaboratory for discovery and innovation. Mr. Rohler joined Purdue University in 2009 as a senior software engineer. In this position, he led the transition of the NEES project from San Diego Super Computer to Purdue. This included determining requirements, designing the system, procuring the hardware and software and finally installing and debugging until a complete working system was ready for release.

Mr. Rohler's education includes a BA in Electrical Engineering Technology from Purdue University and a minor in embedded microcontroller systems from Purdue at Indiana University/ Purdue in Kokomo, IN.

Before coming to Purdue, Mr. Rohler spent 20 years in industry working for General Motors and Delphi Automotive Systems. He spent the first six years as an advanced manufacturing test engineer developing test hardware and software to verify the proper assembly of airbag controllers. The following six years he spent in production/operations as a test engineer and surface mount process engineer. With formal training in software engineering, he transferred to the adaptive cruise control team where he developed embedded software for a cruise control component which utilized an in-car radar system. Next, Mr. Rohler moved into the systems engineering support role where he helped support communication devices used to communicate between a computer and the automotive electronic component. Mr. Rohler finished his career with Delphi as a technical manager of a Delphi facility in the Purdue Research Park in West Lafayette, IN. In this role, he managed up to 80 Purdue college students (sophomore, junior, senior) from the college of engineering (EE & ECE), college of technology (EET) and college of computer science (CS). These part-time students were part of an independent test and verification process where they tested and verified automotive electronic components against engineering requirements

Nathan Sharp

Validation Engineer » nsharp@purdue.edu » 765.496.1092

Composites Manufacturing & Simulation Center

purdue.edu/cmsc

BIO

Nathan received his Bachelor's of Science in Mechanical Engineering in 2010 from Brigham Young University. He received his Master's in Mechanical Engineering from Purdue University in 2012 in signal processing and nondestructive testing. He received his Ph.D. in Mechanical Engineering from Purdue University in 2015 in material characterization and manufacturing process modeling of carbon fiber composite materials. Since graduation, Nathan has been employed as a Validation Engineer for the Composites Manufacturing and Simulation Center (CMSC) at Purdue University. Research interests include manufacturing process modeling and validation, material characterization, and uncertainty quantification of composite materials.

PUBLICATIONS

J. O. Mares, J. K. Miller, N. D. Sharp, D. S. Moore, D. E. Adams, L. J. Groven, J. F. Rhoads and S. F. Son. Thermal and mechanical response of PBX 9501 under contact excitation. Journal of Applied Physics, Vol. 13, Issue 8 (2013).

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Eric Smoldt

Director of Visual Communication » esmoldt@purdue.edu » 765.494.2258

Composites Manufacturing & Simulation Center

BIO

Eric Smoldt has been a professional graphic artist for over 20 years. He has worked for corporate clients such as McDonald's, Caterpillar, and Elgin Sweeper Company, as well as several colleges and universities. He attended Judson College, in Elgin, IL, earning a degree in Visual Communication, and spent his first year after college working as a freelance illustrator. From there he joined Kragie Newell Integrated Marketing and Communications (Des Moines, Iowa) as an Art Director/Illustrator. Following that he opened Group 3, Inc. Des Moines' only imaging/illustration studio. Upon selling the studio, he began his career in academia as the Senior Graphic Designer for Des Moines Area Community College. He started at Purdue University in 2005 as a graphic designer for Purdue Marketing and Communications. He next worked for The Energy Center, in Discovery Park, as the Marketing and Communication Specialist. Following this he worked as the Assistant Director of Visual Communication for Purdue's Division of Recreational Sports. In 2016 he became the Director of Visual Communication for the Composites Manufacturing and Simulation Center within the College of Engineering at Purdue.

purdue.edu/cmsc

Composites Manufacturing & Simulation Center

Ronald J. Steuterman

Managing Director, IN-MaC & CMSC » steuterm@purdue.edu » 765.494.4437

Composites Manufacturing & Simulation Center

purdue.edu/cmsc

BIO

Ronald J. Steuterman is managing director for IN-MaC, Indiana's Next Generation Manufacturing Competitiveness Center, and CMSC, the Composites Manufacturing & Simulation Center, which houses Purdue's portion of the Institute for Advanced Composites Manufacturing Innovation (IACMI). IN-MaC is a state funded program focused on rebuilding manufacturing competitiveness in Indiana and the United States via a comprehensive, integrated approach that includes education from K-12 through to the PhD, strong links to applied research and technology transfer, and fluid connection to Purdue's leading edge research programs. IACMI, a DOE funded Manufacturing Innovation Institute led by the University of Tennessee, was awarded in 2015 and is focused on bringing cost competitive manufacturing of composite material components to automotive, wind, and gas storage applications. Purdue hosts the Manufacturing Design, Modeling, and Simulation Technology Area, one of five Technology Areas within IACMI.

Mr. Steuterman's education includes a BS Industrial Management (engineering minor), Purdue University, MS (Management/ Finance), Purdue University, PhD studies in Purdue University's College of Education, certification as a Phillip Crosby Quality Education System instructor, and various courses in intellectual property, technology licensing, and joint venture negotiation and management, taken at the World Trade Institute, Association of University Technology Managers, and Licensing Executive Society.

Steuterman joined Purdue in 1995 following 18 years in industry. His past university roles include serving as managing director for Purdue's Energy Center in Discovery Park beginning with its inception in 2005, associate director of Purdue University's Burton D. Morgan (BDM) Center for Entrepreneurship, director of the National Science Foundation and Lilly Endowment funded Innovation Realization Lab (IRL), and associate director of corporate and foundation relations. Mr. Steuterman's past business experience includes the launch of Western Petroleum Services International Company, a captive entity of The Western Company of North America (WCNA). He was responsible for the company's joint venture development and technology transfer programs in South America and Europe, generating $700K in annual profits within four years of start-up. Immediately prior to joining Purdue Mr. Steuterman served as Assistant Treasurer for WCNA, managing cash balances of $100 million and assisting in the negotiation of a $450 million acquisition loan facility. His career at WCNA and earlier at Texas Instruments also included assignments in corporate planning, systems development, and marketing

Alejandro Strachan

Professor » strachan@purdue.edu » 765.496.3551

BIO

Alejandro Strachan is a Professor of Materials Engineering at Purdue University and the Deputy Director of the Purdue's Center for Predictive Materials and Devices (c-PRIMED) and of NSF's Network for Computational Nanotechnology. Before joining Purdue, he was a Staff Member in the Theoretical Division of Los Alamos National Laboratory and worked as a Postdoctoral Scholar and Scientist at Caltech. He received a Ph.D. in Physics from the University of Buenos Aires, Argentina, in 1999. Among other recognitions, Prof. Strachan was named a Purdue University Faculty Scholar (2012–2017), received the Early Career Faculty Fellow Award from TMS in 2009 and the Schuhmann Best Undergraduate Teacher Award from the School of Materials Engineering, Purdue University in 2007.

Professor Strachan's research focuses on the development of predictive atomistic and molecular simulation methodologies to describe materials from first principles, their application to problems of technological importance and quantification of associated uncertainties. Application areas of interest include: coupled electronic, chemical and thermo-mechanical processes in devices of interest for nanoelectronics and energy as well as polymers and their composites, molecular solids and active materials, including shape memory and high-energy density materials. He has published over 120 articles in the peer-reviewed scientific literature.

SELECTED PUBLICATIONS (OUT OF OVER A TOTAL OF 120)

"Free volume evolution in the process of epoxy curing and its effect on mechanical properties" Chunyu Li and Alejandro Strachan Polymer 97, 456-464 (2016).

"Shockwave Energy Dissipation in Metal–Organic Framework MOF-5", Kiettipong Banlusan and Alejandro Strachan, J. Phys. Chem. C, 120 12463–12471 (2016).

"Atomic origin of ultrafast resistance-switching in nanoscale electrometallization cells", Nicolas Onofrio, David Guzman, Alejandro Strachan, Nature Materials. 14, 440–446 (2015).

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Tian Tang

Software Engineer » tang298@purdue.edu » 765.496.1087

RESEARCH INTERESTS

Structural Mechanics (Composite/Smart/Multifunctional Structures), Micromechanics (Composite/fabrics/Smart/ Multifunctional Materials), Forming simulations of composite textiles, Multi-scale modeling, Fatigue and fracture, Finite element method, Solid mechanics, Mechanics of Materials, Stress analysis

CURRENT RESEARCH FOCUS

Current research focused on three primary areas:

Multiscale modeling of draping composite textiles

This focus of this research is to develop multiscale modeling framework to simulate the draping behavior of composite textiles such as woven fabrics, non-crimp fabrics, and unidirectional fabrics. This modeling framework was constructed by seamlessly connecting a micromechanics model developed based on SwiftComp and a draping model developed based on PAM-FORM. The open source code TexGen was used to generate the microstructure of unit cell of composite textiles. This modeling technique aims to provide an efficient and accurate computational tool to evaluate the draping behavior of composite textiles.

Modeling of thermoforming textile reinforced polymer

A thermoforming model was built based on PAM-FORM to analyze the thermo-formability and predict the final fiber orientations of textile reinforced polymer for automotive applications. The variations of material properties of textile reinforced polymer with temperature were predicted by a micromechanics model and verified by the experimental results. The goal of the development of this model is to help industry choose right tooling design and material properties.

Development of a model chain for textile reinforced composite structures

This research focuses on creating a model chain by connecting PAM-FORM, PAM-RTM, COMPRO, SwiftComp, and ABQUS. The simulations performed by each software are connected by information flowing through different software. This model chain is expected to predict the influences of manufacturing processes from draping to demolding on the performance of textile reinforced composite structures made by resin transfer molding (RTM).

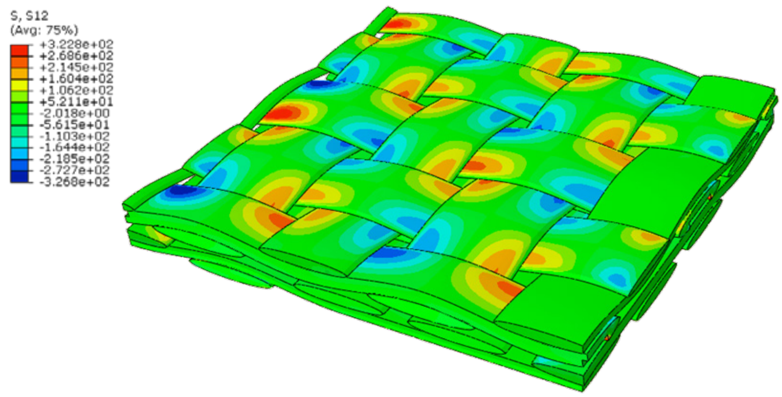
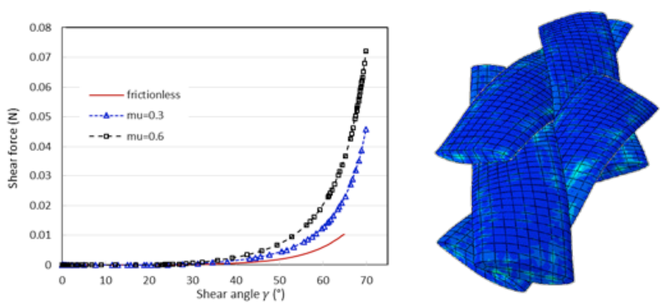


Figure 1. Stress distribution within a unit cell of composite textile predicted by micromechanics model.



(a) (b)

Figure 2. (a) Variation of shear force with respect to shear angle at various coefficients of friction between the yarns; (b) 5 Deformed geometry of a woven fabric at a shear locking angle.

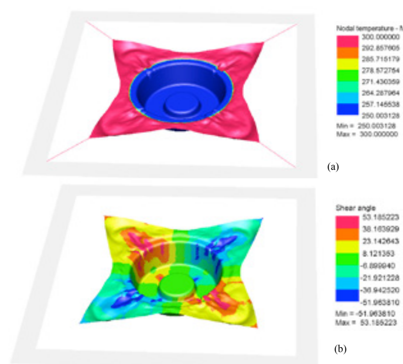


Figure 3. (a) Temperature distribution and (b) shear angle distribution of a thermoformed spare tire well.

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