UW Research and Education in Advanced Composite Materials and Structures

Presented to
Preliminary Working Meeting on the FAA Center of Excellence on Advanced Materials in Transport Aircraft Structures (AMTAS)

By
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January 29, 2004
Acknowledgement

- Sincere Thanks to Senator Cantwell and Staff, The Boeing Company, UW College of Engineering, Industrial and Academic Partners for Their Strong Support and Efforts

- A Special Thank to Dr. Larry Ilcewicz, Dr. Dave Swartz, and Mr. Hank Offermann of the FAA for Initiating and Supporting the FAA Center of Excellence
A&A Faculty Involved in Aerospace Composites Research

- **Kuen Y. Lin, Professor**
  - Composite Materials, Finite Element Methods, Fracture Mechanics, Structural Analysis

- **Eli Livne, Professor**
  - Aeroelasticity, Aeroservoelasticity, Multidisciplinary Optimization, Airplane Design

- **Todd Anderson, Affiliate Associate Professor**
  - Composite Materials, Finite Element Analysis, Solid Mechanics, Manufacturing/Rapid Prototyping

- **Keith A. Holsapple, Professor**
  - Solid Mechanics, Finite Element Methods, Hypervelocity Impact, Asteroids
Recent Research Topics (K. Lin)

- Reliability-Based Damage Tolerant Design Methodology for Composite Structures (Boeing 7E7 PD Group)
- Structural Design Methodology Based on Concepts of Uncertainty (NASA)
- Aging Effects on CAI, Notched Strength and Interlaminar Toughness (NASA/Boeing)
- Nonlinear Thermo-Viscoelastic Analysis Methods for Composites (Boeing/NASA)
- Development of Repair Methods for Composite Structures (Navy, Heatcon, Boeing)
- Durability of Polymeric Composites at Elevated Temperature (Boeing)
- Fundamental Impact Damage Analysis and Test (NASA/Boeing)
- Micro/Macro Fracture Analysis and Experiment (Navy/Flow Research)
Recent Research Topics (E. Livne)

- Structural/Aeroservoelastic Modeling and Optimization of Hot Composite Structures for Hypersonic Flight Vehicles
- Integrated Aeroservoelastic Optimization of “Smart” Airplanes Controlled by Advanced Actuation, including Strain Actuation
- Aeroelasticity of Nonlinear Non-Conventional Configurations, including Joined Wings
- Modeling and Design Optimization of Uncertain Aeroelastic Systems
- Sensitivity, Order Reduction, and Approximations in Coupled Structural Acoustic Systems
- Rapid Low-Cost All-Composite UAV Design and Development
ME Faculty Involved in Polymeric Matrix Composite Research

- **Mark Tuttle** (Property characterization; composite structural mechanics and design)
- **Minoru Taya** (Smart materials and structures: shape memory alloys and piezo-composites)
- **Mamidala Ramulu** (Composite manufacturing; abrasive waterjet and conventional machining)
- **Vipin Kumar** (Microcellular foams – potential sandwich core materials)
- **Brian Fabien** (JSF composite duct; composite flywheels)
- **Paul Labossiere** (FE modeling of composite structures and MEMS devices)
- **Joyce Cooper** (Design for environment methodologies; life-cycle assessments; automotive composites)
Recent Research Topics (M. Tuttle)

- Creep of composite laminates (Boeing, NASA, ONR)
- Optimal design of composite structures (Boeing, NASA, NSF)
- Ultimate Strength of Graphite Fibers (Boeing)
- Composite compressive strengths and buckling of stiffened and unstiffened composite panels (Boeing)
- Analysis of sandwich composite panels (NSE Composites)
- Moisture adsorption in sandwich composite panels (Boeing)
- Design/fabrication of a composite support structure for use in a high-energy particle detector (Fermilab)
ME Faculty Involved in Polymeric Matrix Composite Research

- **Raj Bordia** (Continuum mechanics, joining & bonding, matrix and interface development, curing characteristics)
- **Bhagwan “Bud” Das** (Composite materials & processes, design & manufacturing, mechanical & time dependent properties, quality control)
- **Brian Flinn** (Interfacial and mechanical properties, experimental mechanics, microstructural characterization, hybrid composites)
- **Fumio Ohuchi** (Nanotechnology; Surface science)
- **Alex Jen** (Polymer chemistry; Functional polymers)
- **George Mayer** (Mechanical behavior)
- **Memhet Sarikaya** (Nanocomposites; Electron microscopy)
Composite Research Interests

- Processing
- Characterization
- Conductive Composites
- Joining, Bonding & Coatings
- Damage & Repair
- Fracture & Fatigue
- Environmental Effects/Aging Structures
- Effect of Defects on Performance & Reliability
Department of Chemical Engineering

ChE Faculty Involved in Polymeric matrix Composite Research

- **James C. Seferis** (Polymers and their composites, polynanomers, scaling, and process administration)
- **Bradley R. Holt** (Process design and control)

*ChE Research Interests will be presented by Professor James Seferis*
UW Composite Lab Facilities

- **Polymer/Fiber Characterization Equipment**
  - Automated Thermogravimetric Analysis (TGA) systems
  - Automated Differential Thermal Analysis (DTA) systems
  - X-ray diffraction systems
  - Auger Spectrometer
  - Dilatometers
  - Scanning and transmission electron microscopes
  - Optical microscopes (wide array)
  - Image analysis systems
  - Differential Scanning Calorimeter (DSC)
  - Dynamic Mechanical Analysis (DMA)
  - Thermo Mechanical Analysis (TMA)
  - TGA/DTA coupled with Mass Spectrometer
  - Sample prep (mounting, polishing)
  - Chemical Labs w/ hoods (Acid Digestion, etc)
  - Surface analysis: ESCA
  - Surface Analysis: SIMS
  - Atomic Force Microscopy
  - Scanning Tunneling Microscopy
  - Nanoindentation
  - Microhardness testers
UW Composite Lab Facilities

- **Composite Fabrication Equipment**
  - Hot-melt pre-pregger
  - Hot-platen presses (several of various sizes)
  - Autoclaves (several sizes – 1 commercial, remaining built in-house)
  - Vacuum pumps (several)
  - Resin-transfer molding station
  - Slicing/dicing/grinding equipment
  - Water-jet cutter
  - Well-equipped machine shops with modern N/C equipment
  - Forced air convection ovens

- **Structural Testing Equipment**
  - Universal test frames: several, with load capacities ranging from 4.4 kN (1,000 lbf) to 10.7 MN (2.4 million lbf)
  - Servo-control fatigue frames: several, with load capacities ranging from 22 kN (5,000 lbf) to 450 kN (100,000 lbf)
  - Impact Testers
  - Wind Tunnels (three; largest features a 3m-long test section w/ 2.4m x 3.7m cross-section
  - Environmental test chambers (-140C to 1600 C) for test frames
UW Courses in Composite Materials & Structures

- **Aeronautics and Astronautics: K. Lin, E. Livne**
  - AA 432 “Composite Materials for Aerospace Structures”
  - AA 532 “Mechanics of Composite Materials”
  - AA 531 “Structural Reliability and Damage” *(Ilcewicz, Swartz, Safarian, FAA)*

- **Chemical Engineering: J. Seferis**
  - ChE 571 “Polymer Physics and Engineering”
  - ChE 572 “Advanced Polymeric Composites”

- **Material Science and Engineering: R. Bordia, B. Flinn, K. B. Das**
  - MSE 475 “Introduction to Composite Materials”
  - MSE/ME 562 “Introduction to Electronic Composites”
  - MSE/ME 563 “Advanced Composite: Design and Manufacturing”

- **Mechanical Engineering: M. Tuttle, M. Taya**
  - ME 450 “Introduction to Composite Materials and Design”
  - ME 553 “Adhesion Mechanics”
  - ME/MSE 562 “Introduction to Electronic Composites”
  - ME/MSE 563 “Advanced Composite: Design and Manufacturing”
  - ME 599 “Advanced Mechanics of Composite Materials”
UW COE EDGE PROGRAM
(Director: Michael Campion)

• Master’s Degrees in
  – Aeronautics & Astronautics
  – Aerospace Engineering
  – Manufacturing Engineering
  – Materials Science & Engineering
  – Mechanical Engineering

• Non-Degree Programs
  – Composite Design, Manufacturing & Testing (In Development)
  – Fuel Cell Engineering
  – Quality Engineering
  – Fracture/Failure Analysis
  – Digital Signal Processing

• Courses Offered
  – Between 50 and 60 courses each year
  – Two types:
    • Live – “Fly on the wall” approach
    • Pre-packaged – Develop materials specifically for online delivery
UW COE EDGE PROGRAM

Course Access

• **Video**
  – Live Web-Based Streaming Video
  – Video-on-Demand
  – ITFS (local only)
  – UWTV/Echostar
  – Videotapes or CD-ROMs

• **Course Web Pages**
  – Syllabus/Handouts/Assignments
  – Catalyst Tools
  – Streaming Video

• **Online Videoconferencing**
  – Quiz sections, office hours, etc.
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(Director: Michael Campion)

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Workforce Training

- To Work with Boeing LEAD Group (John Eckholt, Michael Richey, Steve Coe, Barry McPherson) to Develop an Integrated Composite Product Lifecycle Management (PLM) Training Curriculum
- Identify the Competencies Required by Engineers and Technicians to Design, Produce, Deliver, and Support Aircraft Composite Structures
- Offer Courses, Workshop, and Certificate Programs to Practicing Engineers
- Integrate CoE Research Findings into Classroom Teaching
- Explore the Concept of Virtual Global Learning Collaboration Center (VGLCC) to Support the 7E7 Extended Enterprise
- Work with Edmonds C.C., WSU, OSU on Additional Educational and Training Programs
Summary

• Aerospace Composite Research Activities at UW Span Over A&A, ChE, MSE, and ME
• Interdisciplinary Pool of Expertise is Ready to Address New Research Issues
• Adequate Laboratory Facilities are Available for Research and Teaching
• Various Composites Courses are Being Offered on Campus and via EDGE Program
• Training Opportunities Exist for Practicing Engineers in Aviation Industry