

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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University of Washington

Department of Aeronautics & Astronautics



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

Department of Aeronautics & Astronautics

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)

Department of Aeronautics & Astronautics

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

Department of Mechanical Engineering

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)

Department of Mechanical Engineering

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)

Dept. of Materials Science & Engineering

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)

Dept. of Materials Science & Engineering

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 PRORAM

(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 PRORAM

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.

The screenshot shows a Microsoft Internet Explorer browser window displaying a video player and a slide. The video player shows a man in a suit speaking. The slide, titled "Main Factors Affecting the Cutting Process", features a central circle labeled "Cutting process" surrounded by six categories of factors:

- Cutting tool**
 - Material
 - Geometry
- Workpiece**
 - Material
 - Geometry
 - Rigidity
- Machine**
 - Power
 - Rigidity
- Cutting Conditions**
 - Cutting feed
 - speed
 - Depth of cut
- Clamping of tool and workpiece**
 - Rigidity
 - Forces
- Cutting fluid**
 - Type
 - Amount

The slide also includes a navigation bar at the bottom with "Display Slide - 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15" and a "My Computer" icon.

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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