



FAA Center for Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS)

part of the FAA Joint Advanced Materials & Structures Center of Excellence

2005 ACCOMPLISHMENTS REPORT

(covers time period of December 2003–October 2005)

Submitted by:

Mark Tuttle, AMTAS Director
University of Washington
October 26, 2005

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OVERVIEW

FAA Center for Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS)

Established December 2003

University of Washington, lead

Washington State University

Oregon State University

Edmonds Community College

<http://depts.washington.edu/amtas/>

The FAA Center of Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS) is a consortium of academic institutions, aerospace companies, and government agencies. AMTAS seeks solutions to problems associated with existing, near- and long-term applications of composites and other advanced materials in large transport commercial aircraft.

AMTAS' mission is to lead the aviation community by researching new ideas in advanced materials, educating and training aviation professionals, and facilitating knowledge transfer among industry, government, and academia.

AMTAS-sponsored activities are grouped into the following three areas:

Research. Perform studies related to composite materials and structures used in transport aircraft as well as the application of new nanotechnologies to transport aircraft.

Education. Train new and existing engineers and technicians through degree programs and short courses to ensure an educated workforce in the aerospace industry.

Knowledge Transfer. Foster knowledge exchange between government agencies, industry, and academia. Planned activities include seminars, workshops, presentations, and conferences.

Staff

Mark Tuttle, Ph.D., Director, University of Washington, 206-685-6665, tuttle@u.washington.edu

Kuen Lin, Ph.D., Co-Director, University of Washington, 206-543-6334, lin@aa.washington.edu

Ellen Barker, Assistant to the Director, University of Washington, 206-543-0299,

nelle@u.washington.edu

FAA Program Manager

Curtis Davies, 609-485-8758, curtis.davies@faa.gov

Affiliated Faculty: 14; see Table 1

Students: 9; see Table 2

Projects: 7; summarized in Ongoing Projects section



ACCOMPLISHMENTS

PROJECTS (See also "Ongoing Projects" section.)

Note: This project is not technically completed, but this section reflects the "output" that the Center has been established (staffing, website, constituency).

1. **FAA Project: Administration of the FAA Center for Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS)**

PI

Mark E. Tuttle, Ph.D., University of Washington Dept. of Mechanical Engineering

Overview

In December 2003, the FAA announced a joint award to the University of Washington and Wichita State University to create a new Air Transportation Center of Excellence for Advanced Materials (JAMSCOE). This award established two centers, one led by the University of Washington and the second led by Wichita State University. The UW center is named the FAA Center for Advanced Materials in Transport Aircraft Structures (AMTAS).

AMTAS academic members include the UW, Washington State University, Oregon State University, and Edmonds Community College. As lead institution of AMTAS, the UW is responsible for overall administration of AMTAS, oversight of AMTAS projects conducted by all academic members, hosting of semiannual AMTAS meetings, and co-hosting with Wichita an annual technical meeting.

Progress

Staffing:

By September 2004, the Center staff was complete. AMTAS staff includes:

Mark Tuttle, Ph.D., Director, 206-685-6665, tuttle@u.washington.edu

Kuen Lin, Ph.D., Co-Director, 206-543-6334, lin@aa.washington.edu

Ellen Barker, Assistant to the Director, 206-543-0299, nelle@u.washington.edu

Website:

An AMTAS website/logo was developed and made public on November 29, 2004:
<http://depts.washington.edu/amtas/>. The site is updated regularly.

Mailing Lists:

Through a variety of sources including events and referrals, AMTAS has developed a contact list of more than 250 people.



ONGOING PROJECTS

PROJECT TITLE 1

Administration of the FAA Center for Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS)

Abstract

In December 2003, the FAA announced a joint award to the University of Washington and Wichita State University to create a new Air Transportation Center of Excellence for Advanced Materials (JAMSCOE). This award established two centers, one led by the University of Washington and the second led by Wichita State University. The UW center is named the FAA Center for Advanced Materials in Transport Aircraft Structures (AMTAS).

AMTAS academic members include the UW, Washington State University, Oregon State University, and Edmonds Community College. As lead institution of AMTAS, the UW is responsible for overall administration of AMTAS, oversight of AMTAS projects conducted by all academic members, hosting of semiannual AMTAS meetings, and co-hosting with Wichita an annual technical meeting.

PI

Mark E. Tuttle, Ph.D., University of Washington Dept. of Mechanical Engineering

Student(s)

None

Progress

Events:

Since the inception of the Center in December 2003, AMTAS has held, co-hosted and/or participated in eight meetings. Details about these events are found in the "Information Dissemination" section.

1. Preliminary Working Meeting, 1/29/04, Seattle, Washington; 30 attendees
2. AMTAS Autumn 2004 Semiannual Meeting, 11/10/04, Seattle, Washington; 41 attendees
3. Composites Maintenance Workshop, 11/30–12/2/04, Renton, Washington; 64 attendees
4. FAA Centers of Excellence 4th Joint Meeting, 3/14–16, 2005, Orlando, Florida
5. AMTAS Spring 2005 Semiannual Meeting, 4/14/05, Edmonds, Washington; 53 attendees
6. JAMS 1st Technical Review meeting, 5/24–26/05, Wichita, Kansas; 60 attendees
7. Composites Maintenance Workshop, 9/13–15/05, Chicago, IL; 60 attendees
8. AMTAS Autumn 2005 Semiannual Meeting, 10/13/05, Seattle, Washington; 55 attendees

Two more meetings are in the planning stages to date:

1. AMTAS Spring 2006 Semiannual Meeting, date TBD, Seattle, Washington
2. JAMS 2nd Technical Review meeting, 6/20–22/06, Seattle, Washington

PROJECT TITLE 2

Development of Reliability-Based Damage Tolerant Structural Design Methodology

Abstract

The overall objective of this project is to develop a probabilistic method to estimate structural component reliabilities suitable for design, inspection, and regulatory compliance. The proposed research spans a three-year period, consisting of two phases of study. The first year focused on methodology development and validation, while the second and third years will concentrate on the application of the developed technology, such as inspection scheduling and maintenance service guidelines.

PI

Kuen Y. Lin, Ph.D., Dept. of Aeronautics and Astronautics, University of Washington

Student(s)

Cary Huang, Dept. of Aeronautics and Astronautics (part time)

Crystal Simon, Dept. of Aeronautics and Astronautics

Research Faculty

Andrey Styuart, Ph.D., Dept. of Aeronautics and Astronautics, University of Washington

The cooperative strategy is to partner this research with FAA and Boeing. The Boeing Company has committed to match the same level of funding from the FAA to support this research. Boeing personnel who are participating in this project are Dr. Cliff Chen, Dr. Razi Hamid, Dr. Matthew Miller from Structures Technology Group, and Dr. Fritz Scholz from Mathematical and Computing Technologies. Additional engineers and scientists from these two units may take part in specific tasks if a need exists. This cooperative arrangement ensures the successful completion and application of research results.

Progress

A progress review meeting for the project was held on August 16, 2005 at the University of Washington. The meeting was attended by Peter Shyprykevich, Manager from the FAA Technical Center, Dr. Kuen Y. Lin, Principal Investigator of the project, and Dr. Andrey Styuart, research staff for the project. During the meeting, work accomplished in Phase I was reviewed. Phase II tasks to be accomplished during 2005-2006 as well as target schedules were established. Detailed descriptions of Phase II tasks are given below:

Task 2.1 Analysis Method Enhancement

The analysis method developed in Phase I will be enhanced to include:

1. Effects of environmental aging and chemical corrosion. The mathematical model of aging will be represented by an Arrhenius type equation to include the empirical UV and fuel degradation. The aging effects will be incorporated into computer software to help designers compare various aging environments and impact of aging/corrosion on the structural reliability.
2. Development of optimum inspection schedule to minimize maintenance cost and risk. Typical algorithms for minimum life cycle cost design will be studied and incorporated into the software. The developed computer program will take into account the factors such as inspection cost and associated repair and downtime costs, cost of consequence of failure and possibly acquisition and operating costs.
3. Development of *databases* and *tools* to automate the entire evaluation process. Such tools may be used as production tools for maintenance planning.

Database on impact damage condition: The goal is to establish a set of standard design damage types along with their frequencies. Each of them has distinct characteristics such as geometry, energy (or any invariant metric), and density that could be correlated. The challenges may include: (a) data mining and grouping, (b) reverse engineering to estimate impact energy with known or best assumed geometry and density, and (c) establish frequencies and exceedances. This needs to be done for each primary structural area. Understandably, engineering judgment and assumptions will play a big role here; nevertheless, it should be acceptable as long as we take every measure conservatively. To do reverse engineering, we may try to simplify the process by making parametric analyses for both metal and composite structures based on a conservative representative configuration for each structural area (e.g., fuselage skin-stringer panels). As such, for a given damage record, we may do interpolation to get an energy estimate based on the descriptions of the recorded damage.

Tools: A "self-explanatory" user-friendly program containing default sets of initial data, perfect help system and sample solutions needs to be developed. Ideally, the tool should be applicable to both maintenance and design. In fact, with full characterization of damage, loads, environments, materials and costs available, this can be used as a single design tool for a unified design (i.e., combining static strength, damage tolerance, inspections and fail-safety) provided reliability-based design is the norm. The tool should be able to be linked with other structural analysis and design optimization programs.

Task 2.2 Methodology Implementation and Regulatory Compliance

This task will focus on the application of the developed methodology. Key to the implementation of the reliability methods is the development of an accidental damage rating system (ADR) that is compatible with the methodology and complies with MSG-3 guidelines. The current development can help industry in two ways:

- i. Finding rational inspection intervals.
- ii. Establishing more reasonable design requirements compared to the present requirements derived from AC-107, etc. In fact AC-107 regulates the residual strength curve depending on the probability of damage detection only. The approach being used in industry is based on an assumption that composite design is primarily driven by damage detectability. There is no connection with real impact conditions. Using our developed method we can demonstrate to the FAA that in some cases the requirements of AC-107 are too conservative, but in some cases they may be insufficient.

During this reporting period, all the work items planned in Phase 1 have been completed. This includes a probabilistic formulation of the inspection intervals for aircraft composite structures subjected to accidental damage, development of analytical models and demonstration of example results.

PROJECT TITLE 3

Combined Global/Local Variability and Uncertainty in Integrated Aeroservoelasticity of Composite Aircraft

Abstract

Develop analytical, computational and experimental capabilities to address “Combined Global/Local Variability and Uncertainty in Integrated Aeroservoelasticity of Composite Aircraft.” Computational capability development will focus on quantification of effects on stiffness of key local effects in composite structures, global aeroelastic/aeroservoelastic analyses capable of evaluating variations and uncertainty to such local effects, and integrated local/global modeling capability of uncertain composite structures. Capabilities for simulation of the effects of control surface nonlinearities on aeroelastic and aeroservoelastic behavior of full scale airplanes will be developed and used to study effects of nonlinearity and uncertainty mechanisms and guide maintenance practices. Simultaneously, an experimental structural dynamic/aeroelastic testing capability will be developed at UW, and tests will be planned & conducted to study the effects of damage on stiffness of components and models.

PI

Eli Livne, Ph.D., University of Washington Dept. of Aeronautics and Astronautics

Student(s)

Levent Coskuner, doctoral student

The Research Team and Its Progress

A post-doctoral research fellow, Dr. Luciano Demasi, was hired. He has the required background in the mathematical modeling of composite aerospace structures, aeroelasticity, structural sensitivity analysis, and structural optimization. Dr. Demasi completed an intensive course of study in Reliability and Uncertainty Analysis of Structures in preparation for his work on the Reliability/Uncertainty of composite airframes. He continued working on the integration of a nonlinear structural analysis code with steady aerodynamics for static aeroelastic simulations, and with unsteady aerodynamics for the simulation of nonlinear dynamic aeroelastic behavior. Dr. Demasi is currently developing an interface between NASTRAN – the industry Structural Analysis standard – and SMART, our unique UW aeroservoelastic sensitivity and optimization code for actively controlled composite airplanes.

A doctoral student, Mr. Levent Coskuner, was hired. He already has the necessary background in structural modeling, structural sensitivity analysis, structural optimization, and aeroelasticity. Mr. Coskuner has just finished creating a time-domain limit cycle oscillation simulation code for LCO analysis of aircraft with structurally nonlinear control surfaces.

Dr. Andrey Styuart, our Reliability / Uncertainty expert has completed a review of frequency-domain and time-domain analysis / sensitivity methods in aeroelasticity. Dr. Styuart has been working to create interfaces between a frequency-domain describing-function LCO code we developed and NESSUS – a NASA Reliability code. Integration of NESSUS with time-domain simulation will be carried out over the next few weeks.

Boeing and FAA interactions: We now have continuous working relations with Boeing in the area of LCO simulation, with focus on the problem of free-play, but with methods development that will allow simulation of other structural nonlinearities and non-linear local structural effects. To validate Boeing LCO results in the case of 2D airfoil / flap configurations, the UW team developed a describing-function method based LCO simulation code for such configurations. Results were generated, and the code was delivered to Boeing. We are now, following Boeing, in the process of moving to 3D general configurations.

Also, to discuss nonlinear structural effects on aeroelastic reliability, a meeting was organized by Mr. Gerry Lakin (FAA, Flutter) in Renton, WA. Participant included flutter and loads experts from Boeing, Duke University, UW, Zona Technologies, and the FAA. The importance of our work, especially the planned experimental work and the tools development for general 3D configurations, is well recognized.

Experimental Capabilities: A final spec and final decision regarding the purchase of a modal testing system are expected before the end of the month. The search for a modal testing system took longer than expected, because of tough competition in this area, cost considerations, the fact that we needed to wait for the 2-year equipment allocation in order to purchase a working system, and our insistence on a thorough evaluation process. Sales and technical representatives from two vendors came to the UW to demonstrate their systems. The last visit took place on 10/19. Planning is already underway for modal / vibration tests of composite empennage structures with multiple interacting nonlinearities, and for subsequent wind tunnel tests.

General Plans

The plans for the aeroelasticity/aeroservoelasticity project involve, from the start, work in two directions simultaneously:

a. Sensitivity analysis and reliability of composite airframes.

In this effort, Finite Element (FE) models of realistic full scale airframe components will be created and used as a basis for the aeroelastic analysis of such components. Using sensitivity analysis, sensitivities of aeroelastic behavior will be calculated, and models of aeroelastic behavior uncertainty due to possible local variation of structural properties will be created. The resulting aeroelastic uncertainty analysis capability will need inputs in the form of structural variation due to damage, material degradation, and environmental effects. Such inputs will be provided by the team working on the FAA funded composites reliability project, and Boeing composite structures experts.

b. Nonlinear structural effects on the aeroelastic behavior of composite airframes.

Analysis and sensitivity-analysis capabilities for nonlinear aeroelastic behavior of real airplanes will be developed. In the first stage of this effort focus will be on the limit cycle oscillation of control surfaces due to structural nonlinearities such as freeplay, nonlinear damping, and any nonlinear structural behavior of hinges and controls surface actuator backup and attachments. The resulting analysis/sensitivity capability will be applicable for both metallic and composite airframe structures, and special attention will be paid to nonlinear structural modes of behavior specific to composites, such as delamination and debonding.

Integration of a. and b.

c. Reliability of structurally nonlinear composite airframes.

The reliability analysis (described in a.) for linear composite airframes will be extended to the nonlinear structural case, and integrated with the research effort described in (b.). The result: reliability analysis for composite airframes covering linear and nonlinear effects.

d. Creation at the University of Washington of a center of expertise for aeroelasticity of composite aircraft. This includes computational and experimental tools as well as engineering know-how.

Plans for the Immediate Future

1. Complete the time domain LCO simulation capability and link with NESSUS
2. Improve root tracking and flutter speed determination in the frequency-domain (describing-function) capability, and complete linking with NESSUS. Address the issue of multiple LCOs.
3. Carry out reliability and uncertainty LCO studies
4. Identify local damage in composite control surfaces, hinges, actuator attachments, support structure that will lead to local structural nonlinearity, and study the effect on nonlinear aeroelastic behavior.
5. Extend 1–5 to the case of general 3D configurations.
6. Test NASTRAN-SMART interactions, and correlate NASTRAN results with SMART results for systems of interest.
7. Use aeroelastic / aeroservoelastic sensitivity analysis in SMART (and NASTRAN) to study aeroservoelastic reliability of composite airframes.
8. Identify sources of local damage / variability in composite airframes and study the effect on local stiffness / damping.
9. Acquire a state of the art modal testing system, gain experience with it, and start using it to test nonlinear composite airframes.
10. With progress in both 1-5 and 6-7 it is expected that at least two papers describing our research work will be written in the next 6 months.

PROJECT TITLE 4

Improving Adhesive Bonding of Composites through Surface Characterizations

Abstract

Peel ply surface preparation for co-bonding and secondary bonding of primary composite structures is becoming more common as the usage of composites is increasing in commercial aircraft. Peel ply surface preparation is attractive from a manufacturing and quality assurance standpoint because it reduces costs and minimizes the human factors present in other surface preparation techniques, such as grinding and grit blasting. However, there is not a fundamental understanding of the process variables that ensure a high quality, durable bond. Our current research has focused on bond quality of surfaces prepared using peel plies from a single source (Precision Fabrics, Inc.) and two epoxy based film adhesives (Metal Bond 1515-3 and AF555). To further understand the effect of surface preparation on the durability of bonded composite joints, surface analysis coupled with mechanical testing and fractography were used to analyze samples prepared using peel ply removal. Surfaces prepared using polyester peel plies resulted in good bonds with both adhesives. Surfaces prepared with nylon peel plies resulted in poor bonds with Metal Bond 1515-3, but acceptable bonds with the AF555 adhesive. These results raise several new questions regarding the effects of peel ply surface preparation on bond quality that will be addressed in the second year of this project.

PI

Brian D. Flinn, Ph.D., PE; Co-PI: Fumio Ohuchi, Ph.D., University of Washington Dept. of Materials Science & Engineering

Student(s)

Molly Phariss, MSE Ph.D. Candidate, Research Assistant
Russell Caspe, MSE Ph.D. Candidate, Research Assistant
Bjorn Ballien, MSE senior, graduated June 2005
Eric Brutke, MSE Senior
Dinda Padmasana, MSE senior

Progress

Several in depth technical interactions have taken place with Peter Van Voast, Will Grace and Paul Shelley (Engineers from Boeing MRD) in the area of interest: bonding of structural composites for commercial transport aircraft. The results of these discussions helped formed the basis for the detailed experimental plan for this project that was presented at the FAA Coordination Meeting for Chemical Characterization Program, December 16, 2004, NIAR, Wichita, KS.

The year 1 milestones identified at the FAA coordination meeting have been completed and include:

- 1) Production, characterization and testing of bonded composite laminate panels to determine:
 - The effect of peel ply material type on surfaces to be bonded and resulting bond quality
 - The effect of peel ply material texture on bond fracture energy
 - The effect of moisture in peel ply material prior to lay-up and curing
- 2) Publication and dissemination of research results
- 3) Exchange of samples with other investigators in the JAMS COE Chemical Characterization Program

Summary of Experimental Findings

The results of mechanical testing demonstrated a significant difference in bond quality when joints are prepared with varying peel ply materials and adhesives.

- 1) All four weaves of polyester peel ply were easily removed from laminate surfaces after curing and created surfaces that bonded well using either adhesive. The surfaces that were generated were in all cases interfacial between the peel ply fabric and the epoxy resin matrix. XPS surface characterization of the surface generated with polyester peel did not detect any anomalous materials on the surface as were found on nylon prepared surfaces. The bond failure was cohesive with average G_{IC} values of 908 and 809 J/m² for adhesives AF555 and MB1515-3, respectively.
- 2) Nylon peel plies were more difficult to remove from the laminate and in some cases could not be removed without damaging the laminates. Finer weaves were easier to remove than coarser weaves. Laminate surfaces prepared with nylon peel plies bonded well with adhesive AF555 (all $G_{IC} > 750 \text{ J/m}^2$; cohesive failure). Laminate surfaces prepared with nylon peel plies bonded poorly with adhesive MB1515-3 (average $G_{IC} < 165 \text{ J/m}^2$; adhesion failure). An explanation for this difference was found using SEM and XPS. The filaments of the removed nylon peel ply were shredded, and small fiber fragments were found on the corresponding composite surface after peel ply removal. This transfer of peel ply material to the bond surface was confirmed when XPS analysis revealed amide groups on the nylon-prepared composite. Adhesive MB1515-3 must have a chemical composition that does not bond well to epoxy surfaces contaminated with amides. Adhesive AF555 is tolerant of some level of amide contamination.
- 3) Precision Fabrics 60001 SRB release films created very poor bonding surfaces with both adhesives, the result of the transfer of the peel ply siloxane coating to the composite surface (confirmed by XPS).
- 4) Peel ply texture or peel ply moisture content had no significant effect on fracture energy or mode of failure.

Ongoing Research

In the second year of this research the focus will be in three areas.

- 1) Does the source of peel ply (different manufacturers) influence surface and hence bond quality?
- 2) Does bonding of laminate surfaces prepared with dry peel plies vs. wet peel plies differ?
- 3) How does the degree of cure of laminates affect bond behavior?

Expected Outcomes

The research findings from this program will provide a better understanding of the role peel ply surface preparation on bonding of composites. This understanding can lead to improvement in composite system compatibility (prepregs, peel plies and adhesives), a greater confidence in adhesive bonds and contribute to the development of QA methods to test the suitability of surfaces for bonding.

PROJECT TITLE 5**The Effect of Surface Treatment on the Degradation of Composite Adhesives****Abstract**

To ensure the longevity of the commercial aircraft fleet, the long term durability of primary aircraft structure must be understood. The degradation of metals and their attachments (mechanical and adhesive) has been rigorously studied over the years. The introduction of composite materials in aerospace applications has presented challenges as methodologies that have successfully been used for metals do not always produce reliable results with new materials. This project will consider the effect of surface treatments on composite adherends and accelerated test methods that may be used to reliably compare their long term degradation. Follow-on projects may consider improving durability using nano-reinforced adhesives.

PI

Lloyd Smith, Ph.D., Washington State University School of Mechanical and Materials Engineering

Student(s)

Prashanti Pothakamuri, first year graduate student

Daniel Stone, ME senior undergraduate student

Additional Personnel

Much of the work has been coordinated through discussions with Peter Van Voast and Will Grace of Boeing and Brian Flinn at the University of Washington.

Progress

A test matrix was developed to consider the effect of surface preparation on composite adhesive degradation. In part 1 of the study, bonded surfaces were prepared from three types of peel ply. The coupons are nearing saturation, after which they will be loaded at 60% of their UTS while immersed in 140F water for up to 4000 hours. After the completion of the environmental exposure their residual strength will be compared. In part 2 of the study the ability of wedge crack coupons to accelerate degradation was considered. The bonded surfaces were prepared as described in part 1. The crack growth rate was slightly higher for the weakest bond, but the cracks of these coupons exceeded the coupon length before the study was complete. These tests are being repeated with longer coupons. Part 2 will be repeated again with compliant adherends once fracture toughness data from part 1 is obtained.

The focus for the year 2 work is directed toward accelerating degradation. To this end double cantilever beam specimens will be exposed to cold air and hot water immersion will under constant and fluctuating load. Adherend surface preparation will include peel ply, sanding and grit blasting. Adhesive degradation will be monitored from crack growth measurements. A prototype load frame has been designed and fabricated. It is currently being evaluated.

PROJECT TITLE 6

Course Development: Maintenance of Composite Aircraft Structures

Abstract

The goal of this proposal is to develop, in conjunction with AMTAS academic and industry partners, a syllabus and course material for a short course addressing the maintenance of composite aircraft structures.

PI

Charles C. Seaton, Edmonds Community College

Student(s)

None

Progress

Terminal Course Objectives (TCOs) have been developed with the input of industry, government, and academic subject matter experts. A workshop was conducted November 30 over a 3-day period. The objective of the workshop was to provide terminal course objectives (TCOs) for a 5-day survey course and laboratory workshop regarding composites repair, and included approximately 50 participants. In addition, 450 essential skills were identified.

Content has been developed for the TCOs by grouping these objectives into 11 major modules. A workshop was held in Chicago (September 13–15 2005) with over 60 subject matter experts to solicit feedback on the content. Incorporation of these comments will be completed in November 2005. Deliverables for 2005 include the TCOs, content and course enhancements, including safety messages, testimonials and laboratory instructions.

Publications

Final preparation of a workshop report that summarizes material developments and feedback from the Chicago workshop is available on the Edmonds Community College website at www.mpdc.biz. The University of Washington will be publishing summaries in the near future.

A final report will be provided by December 31, 2005 to the FAA Technical Center for final review and posting.

Information Dissemination

Ongoing progress and final reports will become part of the AMTAS website, with consideration for including them in the FAA and Society of Automotive Engineers (SAE) website.

The curriculum has been proposed as a 3-hour credit course, subject to approval by Edmonds Community College.

PROJECT TITLE 7

AF555 Hot/Wet Creep Response

Abstract

This is a Boeing-funded project through the AMTAS center, involving shear lap coupons exposed to hot water and creep stress. The objective of this study was to measure the effect of adherend moisture content on a moisture tolerant adhesive.

PI

Lloyd Smith, Ph.D., Washington State University School of Mechanical and Materials Engineering

Student(s)

Prashanti Pothakamuri, first year graduate student

Daniel Stone, ME senior undergraduate student

Progress

Adherends were preconditioned to a dry or 1% moisture content before adhesive bonding into wide area lap shear coupons. They were then exposed to 0, 2, 3, or 4 ksi creep stress while immersed in 140F water for 1000 hours. The residual shear strength was observed to decrease with the applied creep stress to a maximum of approximately 20% of the control shear strength. The average wet adherend shear strength was comparable to the dry adherend shear strength, but slightly less for the 0 hour exposure. Failure surface examination showed primarily adherend failure, occurring in the matrix between the surface resin layer and fibers. The adherends preconditioned with 1% moisture tended to increase the amount of adherend failure slightly.

PUBLICATIONS

Phariss, M.K.M., Flinn, B.D., Ballien, B., Grace, W., and Van Voast, P.J., "Evaluation of Peel-Ply Materials on Composite Bond Quality," Proceedings of the 2005 Fall SAMPE Technical Conference, Seattle, WA, Oct. 31–Nov. 3, 2005, Society for the Advancement of Material and Process Engineering, Covina, CA.

Seaton C.C., "Course Development: Maintenance of Composite Aircraft Structures," Proceedings of the 2005 Fall SAMPE Technical Conference, Seattle, WA, Oct. 31–Nov. 3, 2005, Society for the Advancement of Material and Process Engineering, Covina, CA.

Smith, L., and Mahadevan, R., "Describing Polymer Degradation using Simplified Experimental Measurements," Proceedings of the 2005 Fall SAMPE Technical Conference, Seattle, WA, Oct. 31–Nov. 3, 2005, Society for the Advancement of Material and Process Engineering, Covina, CA.

Tuttle, M. E., "An Overview of the Center of Excellence on Advanced Materials in Transport Aircraft Structures (AMTAS)," Proceedings of the 2005 Fall SAMPE Technical Conference, Seattle, WA, Oct. 31–Nov. 3, 2005, Society for the Advancement of Material and Process Engineering, Covina, CA.

INFORMATION DISSEMINATION

A. 2004–05 AMTAS Semiannual Meetings

I. AMTAS held two meetings in 2004, both at the University of Washington.

1. Preliminary Working Meeting, January 29, 2004 (summary, agenda and attendee list available at http://depts.washington.edu/amtas/events/amtas_04jan/index.html)
2. Autumn 2004 AMTAS Meeting, November 10, 2004 (summary available at http://depts.washington.edu/amtas/events/amtas_04fall/index.html)
 - a. Presentations were made by the following academic and industry partners and are available on the AMTAS website at http://depts.washington.edu/amtas/events/amtas_fall04/presentations.html:
 - 1) Mark Tuttle, AMTAS Director, *AMTAS Administration and Status*
 - 2) Brian Flinn & Molly Phariss, UW Dept. of Materials Science & Engineering, *Improving Adhesive Bonding of Composites through Surface Characterization*
 - 3) Ken Lin, UW Dept. of Aeronautics and Astronautics, *Development of Reliability-Based Damage Tolerant Structural Design Methodology*
 - 4) Lloyd Smith, WSU School of Mechanical and Materials Engineering, *The Effect of Surface Treatment on the Degradation of Composite Adhesives*
 - 5) Charles Seaton, Edmonds Community College, *Course Development: Maintenance of Composite Aircraft Structures*
 - 6) Howard Banasky, HEATCON Composite Systems, *Composite Repair Heating Methods*
 - 7) Eli Livne, UW Dept. of Aeronautics and Astronautics, *Combined Global/Local Variability and Uncertainty in Integrated Aeroservoelasticity of Composite Aircraft* (not available on website)
 - 8) Al Miller, The Boeing Company, *Update on 7E7 Composites* (not available on website)

II. AMTAS held two meetings in 2005.

1. Spring 2005 AMTAS Meeting, April 14, 2005, Edmonds Community College, Edmonds, WA (summary, agenda and attendee list available at http://depts.washington.edu/amtas/events/amtas_05spring/index.html)
 - a. Presentations were made by the following academic and industry partners and are available on the AMTAS website at http://depts.washington.edu/amtas/events/amtas_05spring/presentations.html:
 - 1) Mark Tuttle, AMTAS Director, *FAA Center of Excellence for Advanced Materials in Transport Aircraft Structures/JAMS Administration and Status*
 - 2) Larry Ilcewicz, FAA, *Composite Safety and Certification Initiatives*
 - 3) John Streck, UW Office of Sponsored Programs, *Intellectual Property and Confidentiality Issues for UW and Sister Institutions* (not available on website)
 - 4) Minoru Taya, UW Dept. of Mechanical Engineering, *Structural Health Monitoring for Future Airplanes*
 - 5) Ashley Emery, UW Dept. of Mechanical Engineering, *Composite Repair Heating Methods*
 - 6) Al Miller, The Boeing Company, *How AMTAS Can Support the Aviation Industry*
 - 7) Mark Tuttle, AMTAS Director, *Emerging Concept for Regional Collaborative Strategy for Advanced Composites Research, Education, and Training*

2. Autumn 2005 AMTAS Meeting, October 13, 2005 (summary available at http://depts.washington.edu/amtas/events/amtas_05fall/index.html)
 - b. Presentations were made by the following academic and industry partners and are available on the AMTAS website at http://depts.washington.edu/amtas/events/amtas_05fall/presentations.html:
 - 1) Curtis Davies, FAA, *Joint Advanced Materials & Structures Center of Excellence: Two-year Perspective*
 - 2) Mark Tuttle, AMTAS Director, *AMTAS/JAMS: Status and Future Plans*
 - 3) Charles Seaton, Edmonds Community College, *Course Development: Maintenance of Composite Aircraft Structures*
 - 4) Lloyd Smith, WSU School of Mechanical and Materials Engineering, *The Effect of Surface Treatment on the Degradation of Composite Adhesives*
 - 5) Brian Flinn & Molly Phariss, UW Dept. of Materials Science & Engineering, *Improving Adhesive Bonding of Composites through Surface Characterization*
 - 6) Eli Livne, UW Dept. of Aeronautics and Astronautics, *Combined Global/Local Variability and Uncertainty in Integrated Aeroservoelasticity of Composite Aircraft*
 - 7) Ken Lin, UW Dept. of Aeronautics and Astronautics, *Development of Reliability-Based Damage Tolerant Structural Design Methodology*
 - 8) Rob Albers, UW/Boeing, *AMTAS Regional Advanced Materials Center Overview*
 - a) Bruno Boursier, Hexcel, *Wind Energy*
 - b) Shreeram Raj, Cytec Engineered Materials, *Sporting Goods/Recreation*
 - c) Dave Humphreys, Washington State Ferries, *Marine*
 - d) Steve Coe, The Boeing Co., *Aerospace*
 - 9) *Presentations by AMTAS Industry Partners & New Industries:*
 - a) Bob LaMantea, Intec, *Test Specifications*
 - b) Abdel Abusafieh, Cytec Engineered Materials, *The Challenge of Using Nano-Modifiers to Achieve Multi-Functionality*
 - c) Jason Scharf, C&D Zodiac, *Resin-Infusion Processes*
 - d) John Weller, Janicki Industries, *Janicki Industries Overview*

The Center will host two such meetings each year plus co-host an annual technical meeting with CECAM at Wichita. Locations will vary among member institutions.

B. 2004 Composite Maintenance Workshop

AMTAS sponsored a “Composites Maintenance Workshop,” held at Boeing Longacres in Renton, WA, November 30–December 2, 2004. The workshop attracted 64 attendees from around the world. The objective of the workshop was to provide terminal course objectives for a 5-day survey course and laboratory workshop regarding composites repair, as part of the FAA-funded project with Edmonds Community College (see “Ongoing Projects”). The Workshop summary is available at http://depts.washington.edu/amtas/events/wkshp_11-04/index.html.

C. FAA 2005 Composite Maintenance Workshop

The 2005 FAA Composite Maintenance Training Workshop was held September 13–15, 2005 in Chicago, IL. The workshop goal was to establish standard course content for organizations and educators introducing students to this topic. The curriculum currently being developed will provide an introduction to the maintenance and repair of composite materials used in aircraft products. This workshop is the result of one of AMTAS' FAA-funded research projects. (Visit <http://www.mpdz.biz/> for details.

D. JAMS 2005 Technical Review Meeting

The 2005 Technical Review Meeting for the JAMS COE was held May 24–26, 2005 in Wichita, KS. All AMTAS project PIs participated and their projects were well received. Workshop details are available at

http://depts.washington.edu/amtas/events/jams_05may/index.html or
www.niar.wichita.edu/FAA/FAAJAMS05.

E. Other Presentations

1. Mark Tuttle, "Summary of the AMTAS/JAMS Center of Excellence," presented to the AIAA Pacific Northwest Section Meeting, Seattle, WA, 10/18/05
2. K.Y. Lin, "Research and Education in Aerospace Composites at UW FAA Center of Excellence (AMTAS)," presented to Beijing Institute of Aeronautical Materials (BIAM), Beijing, China, June 17, 2004.
3. K.Y. Lin, "Research and Education in Aerospace Composites at UW FAA Center of Excellence (AMTAS)," presented to the 6th China/Japan/US Joint Conference on Composites, Chongqing, China, June 21, 2004.
4. K.Y. Lin, "The FAA Center of Excellence for Advanced Materials in Transport Aircraft Structures (AMTAS)," presented to Boeing Technology Conference, Irvine, CA, July 19, 2004.
5. K.Y. Lin, "Research and Education in Aerospace Composites at UW FAA Center of Excellence (AMTAS)," presented to IMAST meeting, Ministry of Technology and Innovation, Government of Campania, Italy, December 9, 2004.
6. Lloyd Smith, "The Effect of Surface Treatment on the Degradation of Composite Adhesives," FAA Coordination Meeting for Chemical Characterization Program, NIAR, Wichita, KS, December 16, 2004.
7. Ramachandran Mahadevan, Lloyd Smith, "Describing the Degradation of Polymers," SEM, Portland, OR, June 2005.
8. Lloyd Smith, "Describing Degradation through Weight Measurements, ICCE-12, Tenerife, Spain, August 2005.
9. Lloyd Smith, "The Effect of Surface Treatment on the Degradation of Composite Adhesives," FAA Coordination Meeting for Chemical Characterization Program, AMTAS, Seattle, WA, October 13, 2005.
10. Brian Flinn, "Improving Adhesive Bonding of Composites through Surface Characterization," FAA Coordination Meeting for Chemical Characterization Program, December 16, 2004, NIAR, Wichita, KS. Presentation to be available on NIAR website.
11. Brian Flinn, "Improving Adhesive Bonding of Composites through Surface Characterization," JAMS technical Meeting, May 26, 2005, NIAR, Wichita, KS. Presentation to be available on NIAR website.
12. Brian Flinn, "Improving Adhesive Bonding of Composites through Surface Characterization," AMTAS, October 13, 2005, Univ. of Washington, Seattle WA. Presentation available on AMTAS website.

Accepted 2006 conference presentations:

13. Kuen Y. Lin and Andrey V. Styuart, "A Reliability Method for Assessing Damage Severity in Composite Structures" has been accepted for SAMPE 2006/Long Beach, April 30–May 4, 2006, Long Beach, CA.
14. Kuen Y. Lin and Andrey V. Styuart, "Probabilistic Approach to Damage Tolerance Design of Aircraft Composite Structures" has been accepted for the 1st AIAA Non-Deterministic Approaches Conference, May 1–4, 2006, Newport, RI.

**TABLE 1:
FACULTY AFFILIATED WITH AMTAS**

Name	Univ./Dept.	Expertise	E-mail/Phone
Raj Bordia , Ph.D. Chair and Professor	UW Dept. of Materials Science & Engineering	Processing and mechanical properties of ceramics, ceramic films and coatings, polymers and composites	bordia@u.washington.edu; 206-685-8158
K. Bhagwan Das , Ph.D. Affiliate Professor	UW Materials Science & Engineering	Rapid solidification rate alloys, metal matrix composites, hydrogen embrittlement, stress-corrosion cracking	kbdas@u.washington.edu; 206-543-2600
Brian Flinn , Ph.D. Research Associate Professor	UW Dept. of Materials Science & Engineering	Processing-structure-property relationships of advanced structural materials	bflinn@u.washington.edu; 206-616-9068
Bradley Holt , Ph.D. Associate Professor	UW Dept. of Chemical Engineering	Process design and control	holt@cheme.washington.edu; 206-543-0554
Kuen Lin , Ph.D. Professor	UW Dept. of Aeronautics and Astronautics	Composite materials, finite element methods, fracture mechanics, solid mechanics, structural analysis	lin@aa.washington.edu; 206-543-6334
Eli Livne , Ph.D. Professor	UW Dept. of Aeronautics and Astronautics	Aeroelasticity, aeroservoelasticity, multidisciplinary optimization, airplane design optimization, controls synthesis	eli@aa.washington.edu; 206-543-1950
Fumio Ohuchi , Ph.D. Professor	UW Dept. of Materials Science & Engineering	Nucleation and growth of thin films, surface and interface of electronic materials, physics and chemistry of layered materials, nanostructures	ohuchi@u.washington.edu; 206-685-8272
M. Ramulu , Ph.D. Professor	UW Dept. of Mechanical Engineering	Mechanics of materials, fracture mechanics, fatigue, and advanced manufacturing processes	ramulu@me.washington.edu; 206-543-5349
James C. Seferis , Ph.D. Boeing/Steiner Professor of Polymeric Composite Materials	UW Dept. of Chemical Engineering	Polymers and their composites, polynanomers, scaling, and process administration	seferis@cheme.washington.edu 206-543-9371
Andrey Styuart , Ph.D. Acting Assistant Professor	UW Dept. of Aeronautics and Astronautics	Probabilistic structural design, composite materials; damage tolerance design, aerospace systems	stewav@aa.washington.edu; 206-543-6612
Mark Tuttle , Ph.D. Professor & Chair	UW Dept. of Mechanical Engineering	Applied solid mechanics, viscoelasticity, composite materials, and adhesion mechanics	tuttle@u.washington.edu; 206-685-6665
Lloyd Smith , Ph.D. Associate Professor	WSU School of Mechanical Engineering	Damage, durability and characterization of composite materials; processing science of laminated, textile and randomly oriented polymeric composites	smith@mme.wsu.edu; 509-335-3221
Timothy Kennedy , Ph.D. Professor	OSU Dept. of Mechanical Engineering	Fracture mechanics, composite materials, finite element modeling, and applications of generalized continuum theories	kennedy@enr.orst.edu; 541-737-2579
Charles Seaton FAA Principal Investigator	EdCC Materials & Process Development Center	Composite structure manufacturing	charles.seaton@edcc.edu; 425-640-1830

UW = University of Washington
 WSU = Washington State University
 OSU = Oregon State University
 EdCC = Edmonds Community College

**TABLE 2:
STUDENTS SUPPORTED BY AMTAS PROJECTS**

Current COE-supported students:

Eric Brutke, University of Washington Dept. of Materials Science & Engineering, Senior
Russell Caspe, University of Washington Dept. of Materials Science & Engineering, Ph.D. Candidate,
Research Assistant
Levent Coskuner, University of Washington Dept. of Aeronautics and Astronautics, doctoral student
Cary Huang, University of Washington Dept. of Aeronautics and Astronautics
Dinda Padmasana, University of Washington Dept. of Materials Science & Engineering, senior
Molly Phariss, University of Washington Dept. of Materials Science & Engineering, Ph.D. Candidate,
Research Assistant
Prashanti Pothakamuri, Washington State University School of Mechanical and Materials
Engineering, first year graduate student
Crystal Simon, University of Washington Dept. of Aeronautics and Astronautics
Daniel Stone, Washington State University School of Mechanical and Materials Engineering, senior
undergraduate student

COE-supported students who have graduated as of October 2005:

Bjorn Ballien, University of Washington Dept. of Materials Science & Engineering senior, June 2005