Electron Beam Curing of Composites - An ORNL View of Issues, Activities, and Possibilities

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ORNL View of EB Technology

- Good News
  - Interest Continues to Rise
- Not So Good News
  - There are Still a Number of Issues
- What is Ongoing and What Do We Expect?
  - Industry and Government are Tackling Key Issues

Potential Advantages of EB Curing

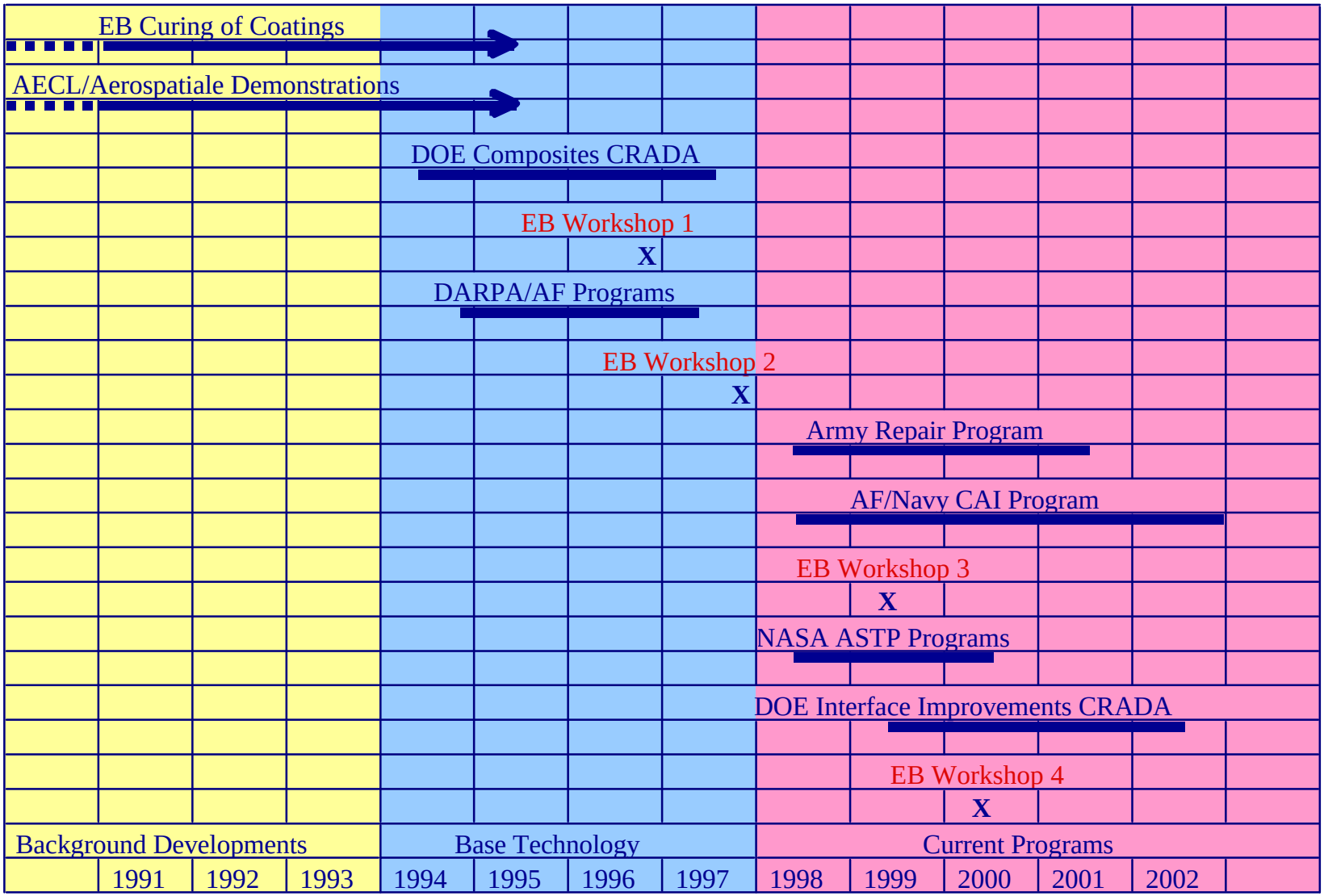
- Inexpensive Tooling
- Long Pot Life
- Minimize CTE Mismatches

	Traditional Thermal Curing	E-Beam Curing
Resin System	Resin and Hardner	Radiation-Sensitive Resin No Hardener Required
Cure Temperature	High	User Selectable
Cure Speed	Slow	Fast

- "Green" and Clean
- Uniform, Volumetric Cure
- Out of Autoclave Process
- Thick Sections (Via X-ray)
- Unique Parts/Processes

Ultimately a More Affordable Process

Growth of Major EB Programs



Other Growth Examples

- Toll Facility Growth
  - "Charter Members" - AECL/Acsion, IRT/Nicolet, EBServices (NJ)
  - New Players - STERIS/Isomedix, EBServices (OH), Neo-Beam, UDRI, SRL
- Technology Dissemination
  - Oak Ridge Workshops
  - Web Sites hits and followup
  - SAMPE, CFA, CIRMS, DMC, ACS, SAE sessions/papers

Technology Issues

Issues - Material Properties

- Materials are Comparable to State-of-the Art Thermal-Cured Materials, but Not Equal:
  - Interlaminar shear strength is low with respect to 977-2 and 977-3 standards
  - Thermo-mechanical properties appear equivalent or in some cases even better
  - Durability and toughness are suspect

Technology Issues (Cont.)

Actions - Material Properties

- Interfacial Properties of Electron Beam Cured Composites CRADA
  - Establishing cause and “cure” for deficient shear properties
- Other Ongoing Efforts at Multiple Organizations Looking at
  - Other Properties
  - Various Processes
  - Adhesives
  - Other Systems

Technology Issues (Cont.)

Issue - Data Availability

- Material Properties Database Not Extensive
  - Large breadth of available materials, depth of information is shallow for many materials
  - Continued optimization discourages downselection
  - No large programs to fund qualification
  - No authoritative data reference
  - Data sources and test methodology have large variation

Technology Issues (Cont.)

Actions - Data Availability

- Number of Programs Now Generating Data
  - CAI and Aerospace Prime IRADs (limited availability)
  - NASA ASTPs and SBIRs
  - Army Programs
- Programs Addressing Qualification Methodology
  - AGATE
  - Navy “mini-qual” thrust
- Most Data Published and Discussed at Conferences and Workshops and on Web Pages

  (e.g. http://www.ornl.gov/orccmt/pages/ebhomepg.html)

Technology Issues (Cont.)

Issue - Process Optimization and Standardization

- Processing Techniques Could Be Improved
  - Process envelope needs definition
  - Compaction steps are cumbersome
- Processing Standards Yet to Be Developed
  - No clear material/process winner for focus
  - No group has defined role for entire process

Technology Issues (Cont.)

Actions - Process Optimization and Standardization

- Number of programs and organizations working on improving processes (ASTP, CRADA, CAI, etc.)
- Need still exists for effort focused on standardization

Technology Issues (Cont.)

Issues - Facilities and Equipment

- EB Facilities and Equipment Are Not Necessarily "Composites Friendly"
  - Facility locations/availability
  - Composites related equipment may not be convenient in most facilities
  - Obstructions due to other operational requirements

Actions - Facilities and Equipment

- New Facilities Opening/ Others Being Developed
- Accelerator Manufacturers and Facility Operators Developing Equipment with Composites Focus

Technology Issues (Cont.)

Issue - Scale-Up

- Scale-Up Issues Still to be Faced
  - Little consensus on overall economics
  - Minimal driver for scaleup
    - Small *current* market for aerospace applications
    - Other industries watching from side lines

Actions - Scale-Up

- Magnitude of Ongoing Efforts Demonstrates Commitment to Technology
- Other Potential Opportunities Being Evaluated

Technology Issues (Cont.)

Issue - Supporting Research Needed

- Cure Mechanisms Not Fully Understood
  - Limited background makes optimization of material systems difficult

Actions - Supporting Research Needed

- Pockets of effort ongoing in CRADA and in other programs

ORNL/DOE EB Programs

Part Under Accelerator

- Electron Beam Curing of Polymer Matrix Composites CRADA
  - Developed breakthroughs in cationic curing chemistry and processing
  - Demonstrated multiple processing options (RTM, layup, winding, etc.)
  - Developed stability data for alternate tooling materials
  - Established economic justification for specific applications

This 3-year $7M CRADA Involved 2 DOE National Labs and 10 Industrial Partners from 1994-1997

ORNL/DOE EB Programs (cont.)

- Interfacial Properties of Electron Beam Cured Composites CRADA (1999-2002)
  - Establishing cause for deficient shear properties (assumed to be fiber-resin adhesion)
  - Determining mechanism(s) responsible for poor fiber-resin adhesion
  - Developing and evaluating resin systems and fiber treatments to improve shear properties
  - Developing refined methods for processing EB-cured composites

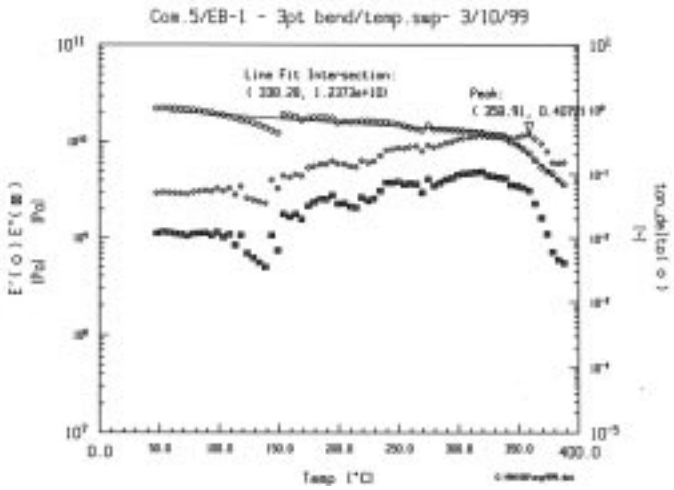
This 3-year $3M+ CRADA Includes 11 Industrial Partners and 4 Government Sponsor/Partners

EB Curing for Comanche

ORNL has been Evaluating EB Cured Materials for Challenging Comanche Issues:

- High temperature tail rotor shaft
  - EB curing provides desirable properties
- Lightweight ballistic protection
  - EB processing degrades some of the materials

Shaft Fabrication



Composite DMA Data

ORNL/NASA EB Collaboration

RLV Technologies

- Air Frame Systems
  - LaRC/GRC/ORNL - EB-cured composite structures
  - LMSW/ORNL - adhesives for cryotank
- Propulsion Systems
  - MSFC/GRC/ORNL - Composite feed lines

Other Research Activities

- FASTRAC Rocket Motor
  - MSFC/ORNL - Composite Feasibility
- High Temperature Composites
  - GRC/ORNL - EB-cured high temperature polymers

Past and Present ORNL EB Efforts

- Materials for Cryogenic Storage Applications
- LONGFOG Integrated Fuel Tank/Air Inlet Prototype
- T-38 Canopy Frame
- Braided Structures for Aircraft
- Low Cost Missile Casings
- Low-Cost Luggage Containers for Blast Protection

LONGFOG Section

Other Complementary Efforts

- Composites Affordability Initiative - Air Force, Navy, and Primes
- NASA SBIRs for Automated Tape Placement and In-situ Curing
- Army Vehicle Programs
- Numerous IRAD Programs within the Defense Community

Potential EB Opportunities

- Thick Section and Other Large Structures such as Naval Ships and Submersibles
- Adhesive Bonding Focus is Expanding
- Lightweight Materials for Transportation
  - Automotive
  - Heavy Vehicles
- Composites for Infrastructure
  - Bridges, Buildings, Barriers, etc.

Summary

- Technology Has Progressed From Formative Stage to Current Emphasis on Applications Development and Targeted Research
- Interest and Opportunities Continue to Grow
- Significant Issues Remain - Most Are Being Addressed
- *Continued Cooperation and Collaboration are Keys to Success*