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Novel Room Temperature Filler for Honeycomb Repairs

2024 JCAMS Annual Meeting

Elizabeth Andrew

MATERIALS / STRUCTURES / COMPOSITES

TRANSFORMING THE MATERIAL CHALLENGES OF TODAY INTO THE SOLUTIONS OF TOMORROW

COMPANY PROFILE

Materials Sciences LLC (MSC) is a small business headquartered in a 25,000 ft^2 combined engineering, laboratory, and prototyping facility in Southeastern PA

- 15,000ft^2 advanced textile production facility and a 30,000ft^2 composite manufacturing facility in Greenville, SC
- 12,000ft^2 engineering and manufacturing facility in Huntsville, AL
- Large scale composites production capability in Gulfport, MS via parent organization Seemann Composites LLC

MATERIAL CHARACTERIZATION

- Test planning, specimen design, data reduction and analysis, material qualification
- Standard coupon (e.g. ASTM, SACMA) and large-scale specialty element/component testing
- Static and fatigue testing – Servohydraulic and electro-mechanical
- Dynamic-modal analysis, DMA, creep, random vibration, shock, system identification
- Environmental conditioning
- Dimensional analysis/3D inspection
- Non-destructive testing

DESIGN AND ANALYSIS

- Computer aided design and solid modeling software:
  - (RHINO, SolidWorks)
- Commercial and in-house finite element programs
  - (ABAQUS, LS-DYNA, ANSYS, FEMAP)
- Proprietary materials analysis and design software
- Topology optimization for additive manufacturing

PROTOTYPE & PRODUCTION MANUFACTURING

- Fabrication of fiber reinforced composite parts
- Out-of-Autoclave (OoA) manufacturing via resin transfer molding (RTM), resin film infusion (RFI)
- Compression molding
- Injection molding
- Textile production

PRODUCT DEVELOPMENT AREAS

MSC has led design, analysis, manufacturing and testing of advanced composite materials and structures for a broad range of product applications for both government and corporate clients. These have included aviation and missile systems, marine and transportation systems, ground vehicle, unmanned systems and high-performance sporting goods.

- **AVIATION AND MISSILE SYSTEMS**
- **MARINE AND TRANSPORTATION SYSTEMS**
- **PRODUCT TEXTILES AND COMPOSITE PARTS**

COMPOSITE DAMAGE MODELS

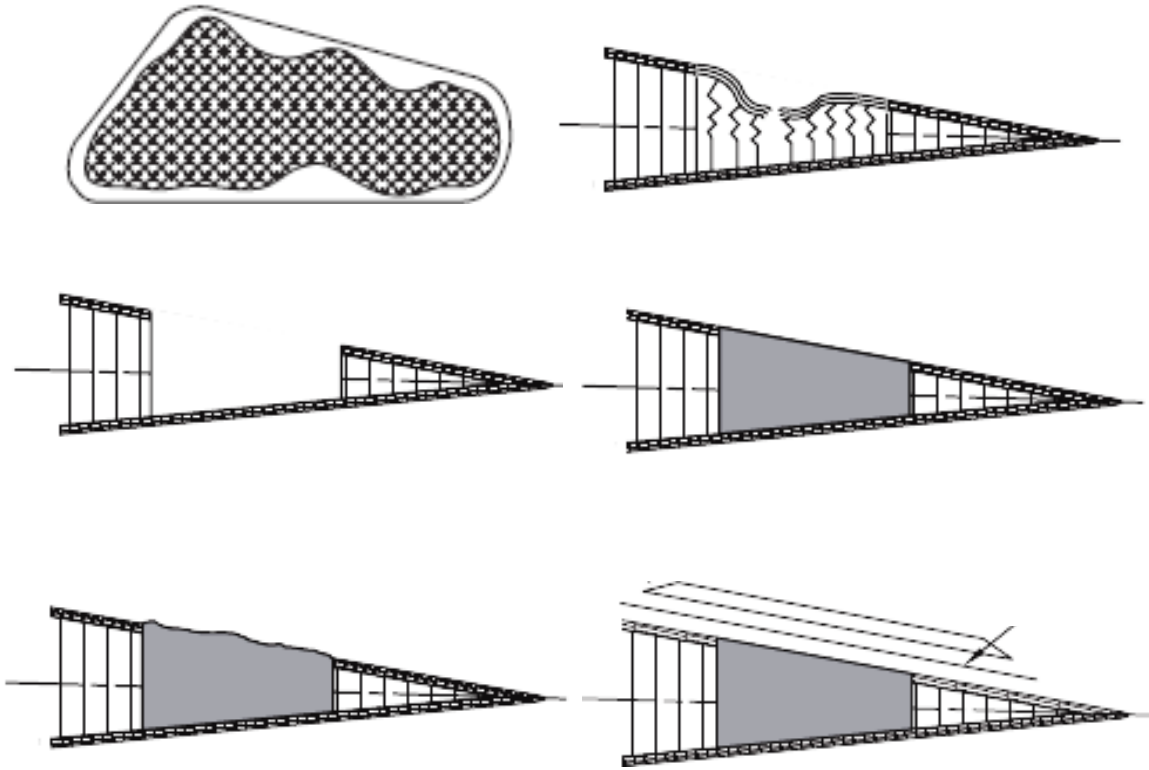
- **MAT 161/162:** Progressive failure model for LS-DYNA and ANSYS
- **NDBILIN:** Stress-based failure modeling for ABAQUS
- **DDSHM:** Fractured-based failure modeling for ABAQUS

BACKGROUND

- Opportunity

  There are two general repair types for sandwich structures: core fill and honeycomb replacement. For large repairs, replacing the honeycomb is currently the only option due to the weight and structural performance attributes associated with state-of-the-art (SOTA) materials. The Navy is seeking a **novel, light-weight, fast-curing filler material** with enhanced mechanical properties that will facilitate larger potting repairs.

- Program Details
  - Customer: NAVAIR
  - Current Funding: Phase II SBIR
  - Topic #: N221-006
  - PoP: 7/26/23 → 8/4/25

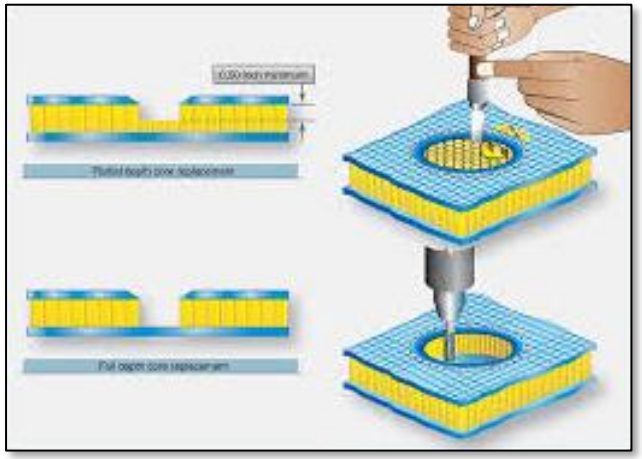


Typical steps to a core fill repair in a sandwich composite

NAVAIR PHII SBIR : PROGRAM GOAL

- **Phase II Objectives:** Demonstrate high-quality repairs that increase operational efficiency
  - Optimized Cure Cycle
  - Increased Glass Transition Temperature (Tg)
  - Reduced Density

- **Approach:** Formulate blended epoxy system(s) with tuned hardener and filler package(s) to achieve desired cure profile, density, and mechanical performance.



- **Anticipated Phase II Results:** An innovative low density honeycomb filler that will be useful in a wide range of environments
  - Retains compressive strength at elevated temperatures
  - Cures rapidly even at very low temperatures
  - Agnostic to application method

RESIN DEVELOPMENT

- Develop base epoxy blend and cure package to achieve desired pot life, exotherm temperature, and cure time

- System Optimization
  - Catalyst Concentration for reaction rate control
  - Fire Retardant package
  - Filler for density reduction
  - Elevated temperature properties

- Additional Focus points
  - Handling characteristics such as viscosity and cling
  - Component shelf life

Processing Objectives

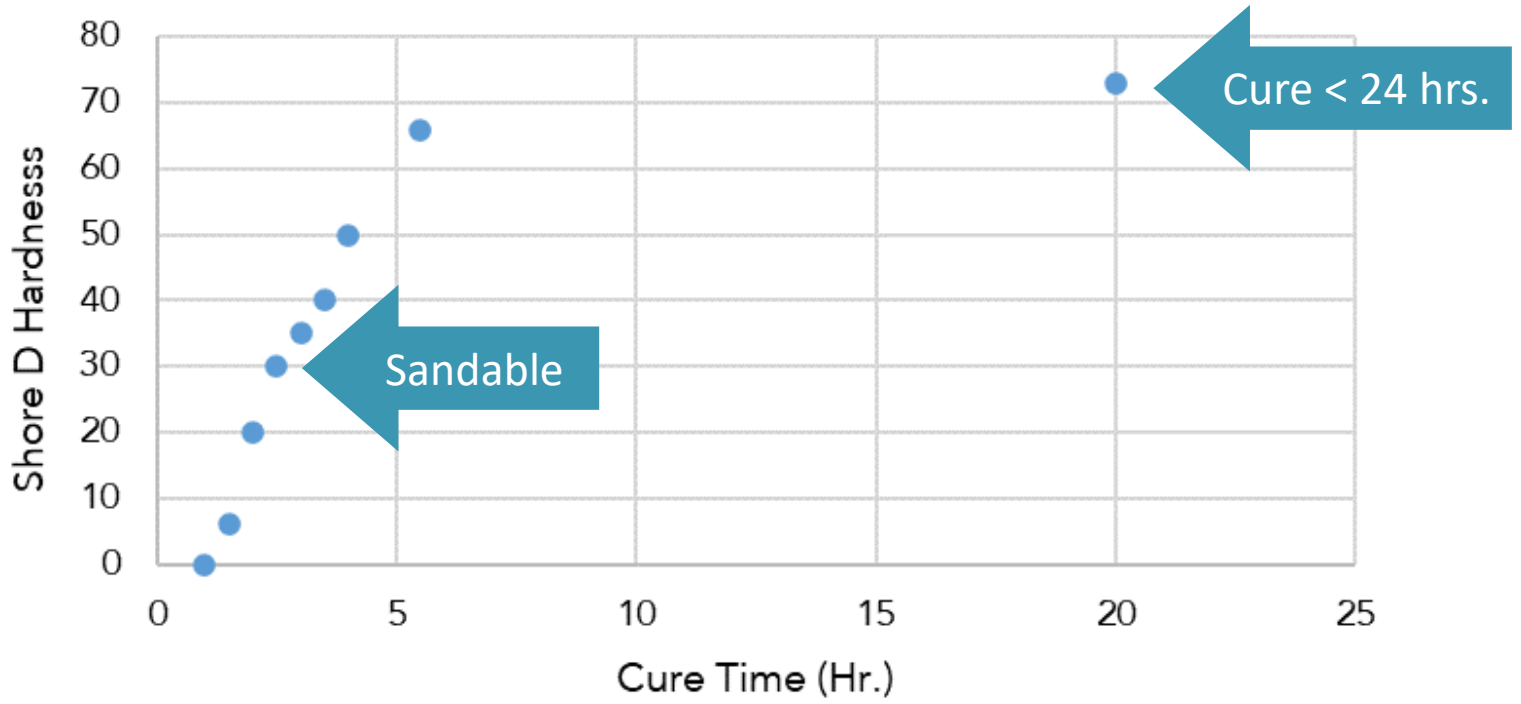
- 8 hr. cure < 70°F (21°C)
- Pot Life > 15 minutes
- 1 hour cure to sanding at 70°F (21°C)
- Exotherm < 200°F (93.3°C)

Material Property Targets

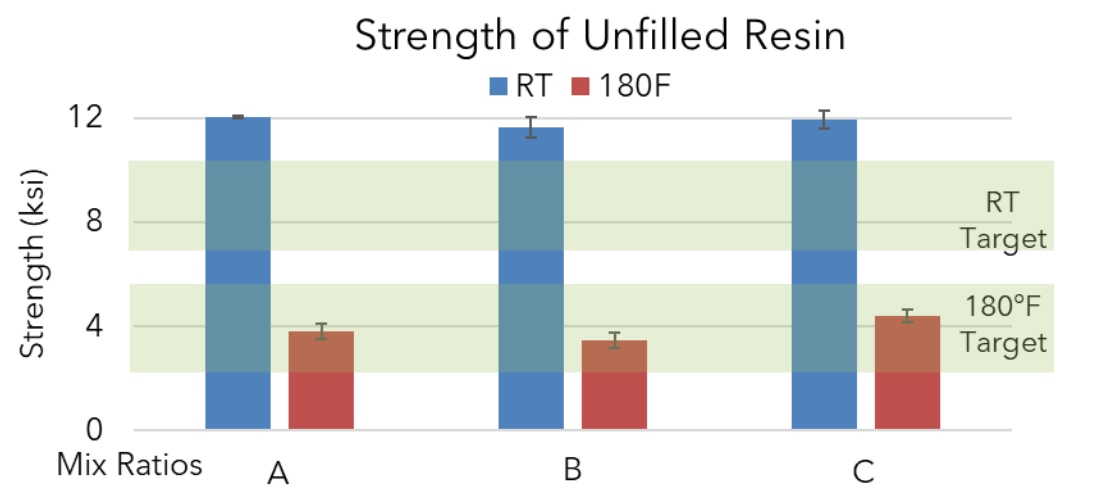
- Compression Strength 7-10 ksi
- Density 0.4-0.8 g/cc
- Surface chemistry
- Processability
- 50% property retention at 180 °F

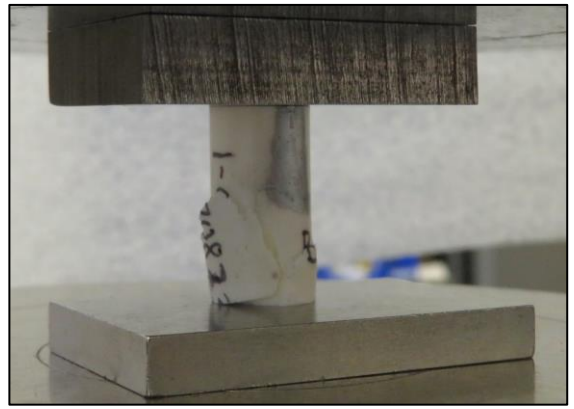
EXTENT OF CURE

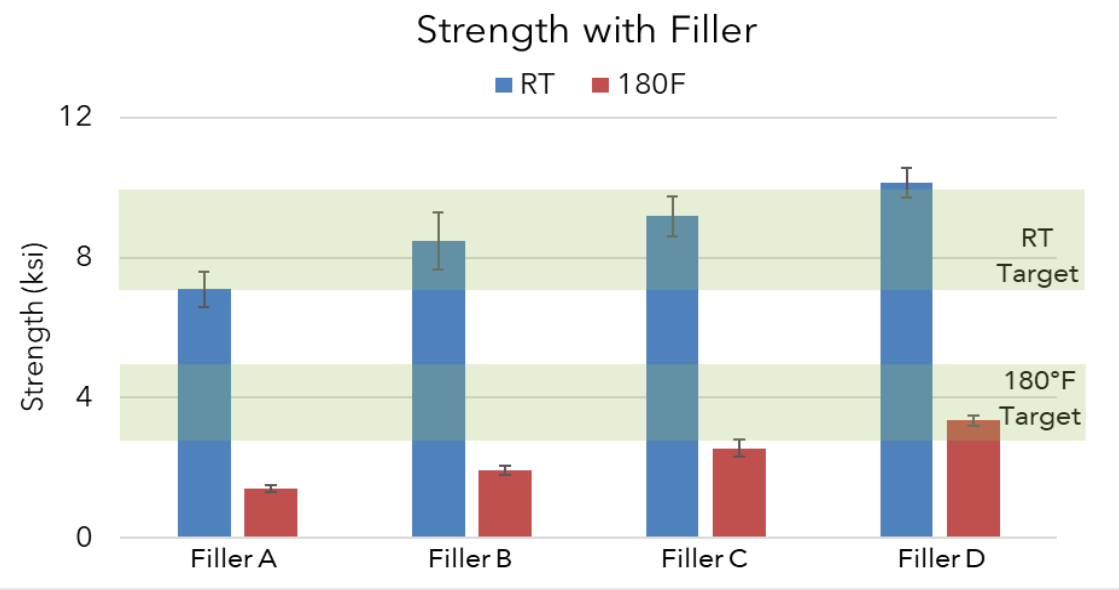
- Shore D is an indicator of the extent of cure
- Highest Shore D value taken at each point

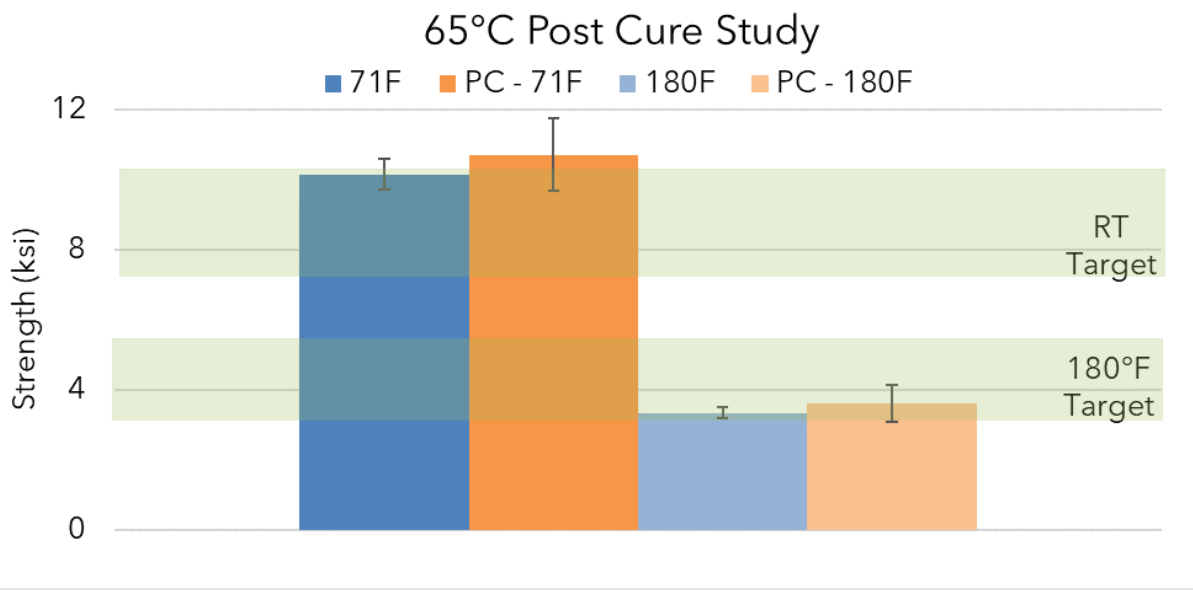


COMPRESSION TESTING



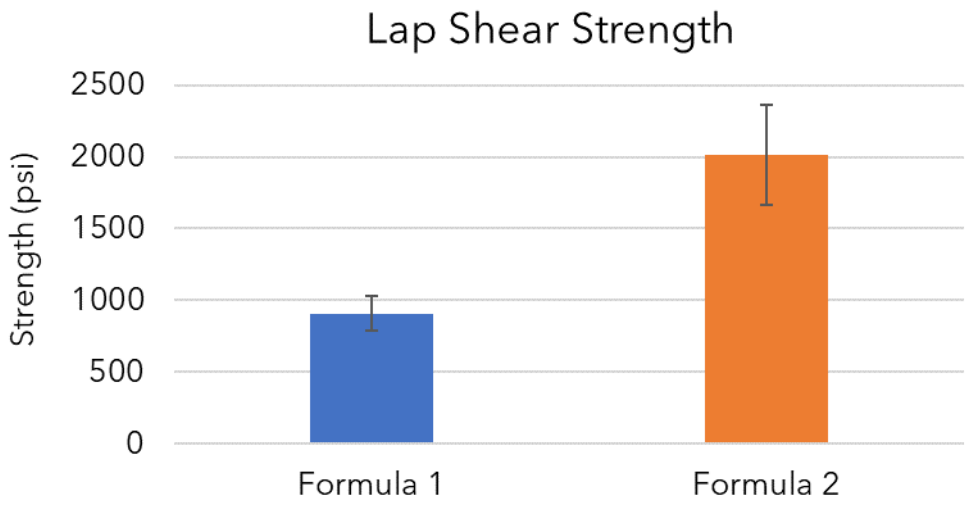




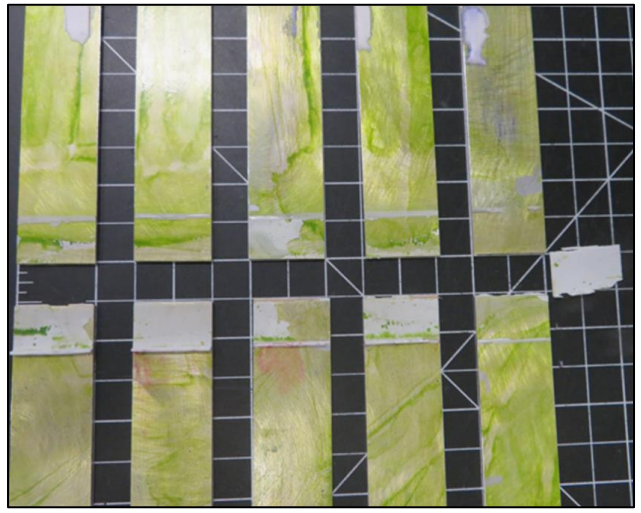


LAP SHEAR TESTING

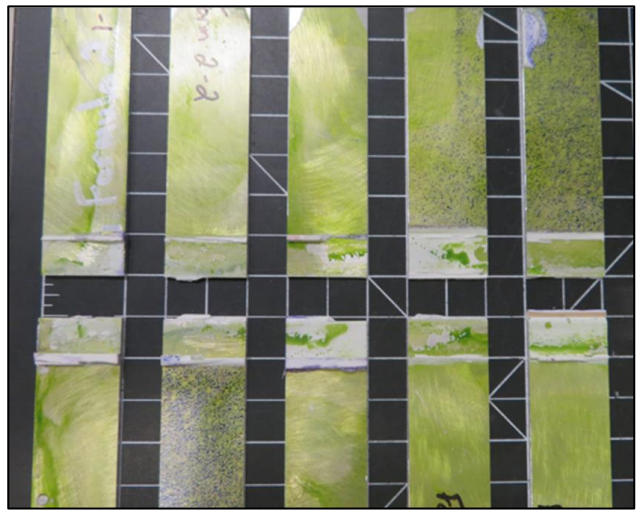
- Aluminum used as adherend
- Prepared according to ASTM D1002
  - Single lap configuration

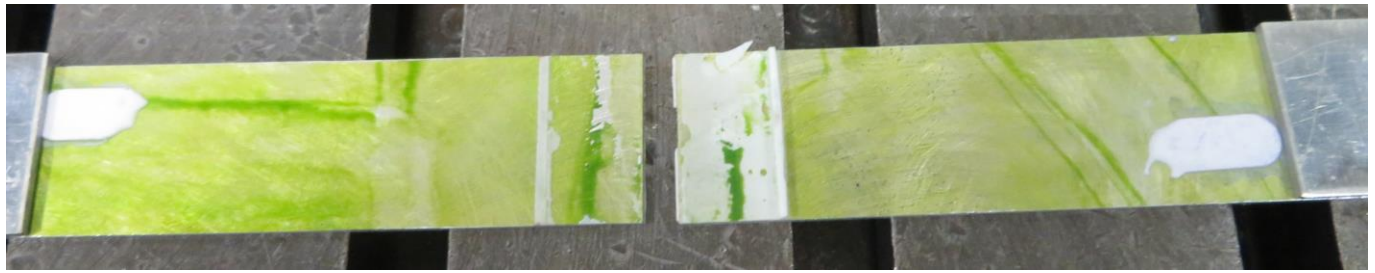


Formula 1



Formula 2





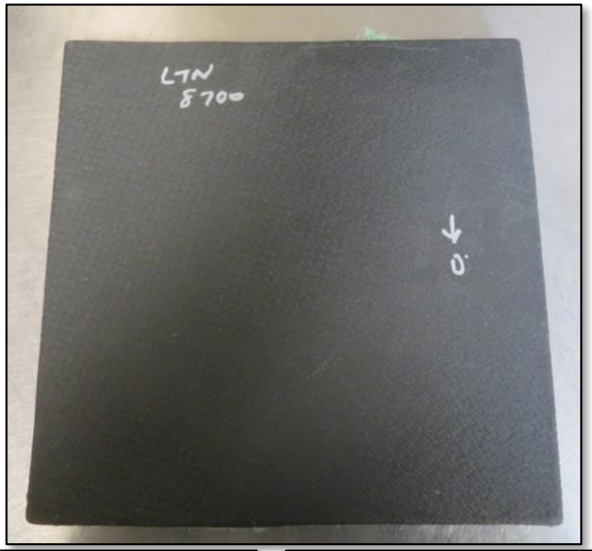
SUPPLEMENTAL CAPABILITY : FR PERFORMANCE

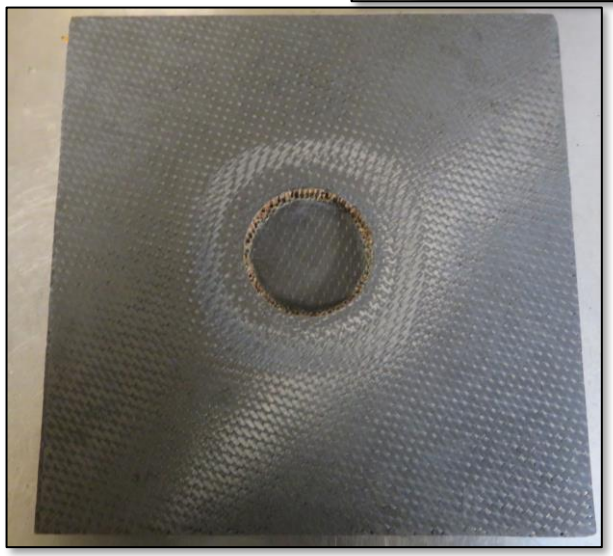
- For large repairs as well as in specific locations, fire retardance is a desirable performance attribute.
  - Filled system is self extinguishing
  - Vertical burn out occurred in 4 seconds
    - No Drips
    - Minimal deformation
  - Very hard char formation

- Corresponds to UL94 Flammability rating of V-0

FOCUS POINT: REPAIR DEMONSTRATION

- Repair shows large efficiency improvement.
  - Rapid application of potting compound
  - Minimal delay to sanding
  - No runaway exothermic reaction
- TRL-4 achieved





PILOT PRODUCTION

- Ross double planetary mixer
  - 2 gallon capacity
  - Fully mixed resin or hardener package
  - Uniform incorporation of fillers

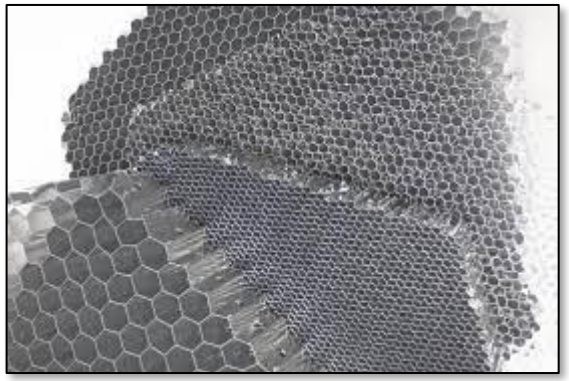
SUMMARY

MSC Solution	Advantages Over Legacy*
Cured in under 24 hours	Cost competitive with potential for savings
Cures as low as 32°F	
Maximum Exothermic Temperature of 31C	40% weight savings
Pot life of 30 minutes	50% (4hr) reduction in time to sand
Density = 0.72 g/cc	80% (4 day) reduction in time to full cure
Compressive strength greater than 8 ksi	-
Lap Shear above 2 ksi	-
UL-94 V0 Fire performance	No fire retardancy

*Loctite EA 9321 AERO

FUTURE WORK

- Higher Temperature Post Curing
- Further Density Reduction
- Evaluation adhesion to other relevant substrates
  - Aramid
  - Aluminum
  - Polymer foams
- Scale up to 40 gallon mix planned for Q4 CY24



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  - Elizabeth Andrew – Engineering Manager
  - Dominic Mirto – Testing SME
  - Clifton Garrett – Composite Technician

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Questions?