THE AIR FORCE RESEARCH LABORATORY
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Composite Aircraft Fire Protection

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Mr. R. Craig Mellerski
Air Force Research Laboratory
Airbase Technologies Branch
and
Dr. Doug Dierdorf
Applied Research Associates, Inc.

Overview

- Background
- Program Objectives
- Preliminary Results
- Initial Conclusions
- Future Efforts

Background

- **Three recent composite aircraft ARFF incidents**
  - F-22 Crash at Nellis AFB, NV, Dec 2004
  - B-2 Crash, Anderson AFB, Guam, Feb 2008
  - B-2 Engine Start Fire, Anderson AFB, Guam, Feb 2010
- **ARFF Lessons Learned**
  - Hidden interior fires are difficult to extinguish
  - Composites smolder and reignite
  - Fuselage penetration is virtually impossible with an axe and difficult with a K-12

Background (2)

- **Air Force Civil Engineering Fire Panel assembled a list of four Key Questions.**

1. How soon must a small fire be extinguished in order to minimize damage from a small fire?
2. What is the best method/agent to extinguish composite fires and prevent reignition?
3. What is the best method to penetrate the fuselage of a composite aircraft?
4. How can bunkers/PPE be cleaned to permit reuse after a composite firefighting operation?

Program Objectives

Objective I. **Develop and validate a model for composite fire damage as a function of fire exposure, apply to relevent small fire scenarios, e.g. APU, Nacelle or Brake Fires.**

Objective II. **Evaluate fire fighting methods and agents versus deep seated composite material fires.**

Objective III. **Evaluate tools and methods for penetrating/cutting composite materials.**

Objective IV. **Determine requirements for PPE cleanliness and methods to accomplish required cleaning.**

Objective I

- **Develop and validate a model for composite fire damage as a function of fire exposure, apply to relevent small fire scenarios, e.g. APU, Nacelle or Brake Fires.**

Technical Approach

- **Develop Damage Model**
  - 1D Model
  - Include Pyrolysis, Charring, Char Burning
- **Apply CFD Fire Model**
  - FLUENT Software
  - Spray fire model with Probability Density Function (PDF) combustion model and Direct Ordinate radiation model
- **Validate Against Experiment**
  - 9 Fires, vary flow rate and total exposure time
  - Collect Temperature, Heat Flux and Composite Residual Strength Data.

Objective II

- **Evaluate fire fighting methods and agents versus deep seated composite material fires.**
  - Extinguishment systems (technologies)
  - Agents
- **Protect assets of US Air Force**

Technical Approach

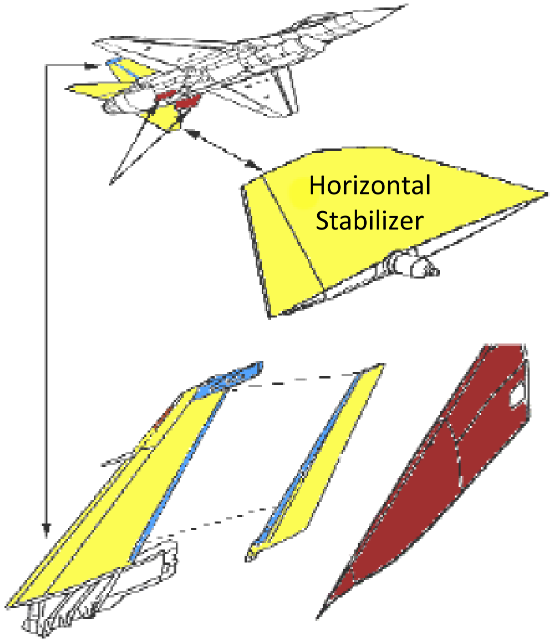
- **Test apparatus**
  - 2 parallel (2’×3’) carbon/BMI panels
  - Each panel under 4-point stress – one in each direction
  - 15° tilt
  - Composites ignited by pool of JP-8
- **Baseline tests**
  - Air-aspirated AFFF
  - 2 gal/min at 100 psi nozzle pressure
  - Firefighter extinguish pool, then composite material

Results to Date

- **Effect of tilt on extinguishment**
  - Positive (vertically 4-pt stressed panel in pool) vs. negative (horizontally 4-pt stressed panel in pool)
  - No significant difference in extinguishment
- **Effect of different technologies on extinguishment**
  - Air-aspirated, non-air-aspirated, compressed-air foam, ultra-high pressure
  - Testing complete, results not completely analyzed
- **Effect of agents on extinguishment**
  - AFFF, FFFP, Class A, Purple K, Heating gel
  - Testing to begin mid-March

Objective III

To identify new tools and techniques that will allow firefighters to more efficiently cut, penetrate and extinguish burning aircraft composite materials. AFRL is using the carbon/epoxy horizontal stabilizers from the F-16.

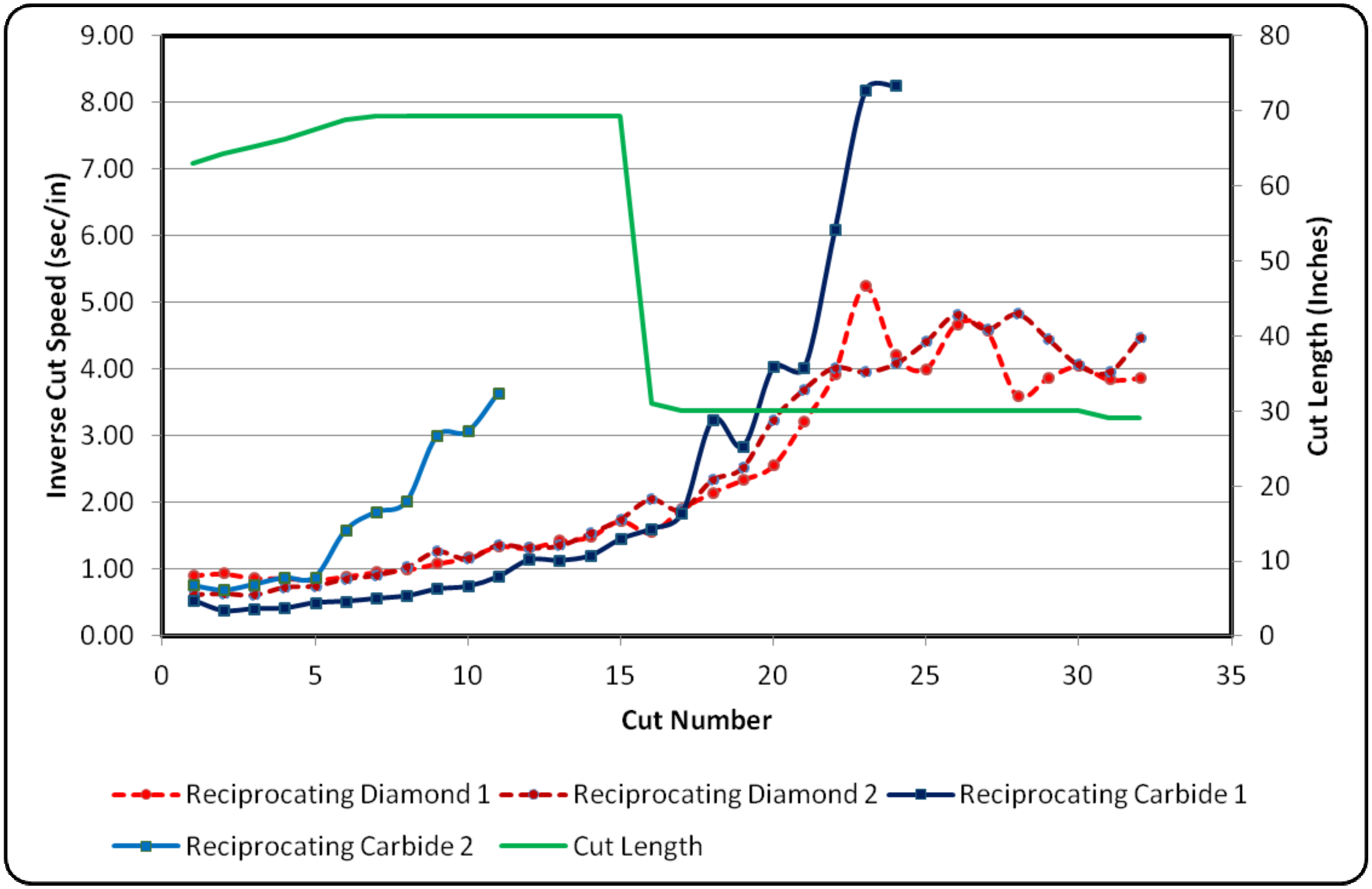


Technical Approach

Evaluate the effectiveness of new cutting technologies to cut, penetrate and deliver agent to deep seated fires. Establish baseline data on cutting and penetration of composite materials using existing equipment. Evaluate new cutting technologies to determine the quickest, safest method for cutting away sections of composite aircraft to reach deep-seated fires. Evaluate new tools for extinguishment of hidden/smoldering fires.

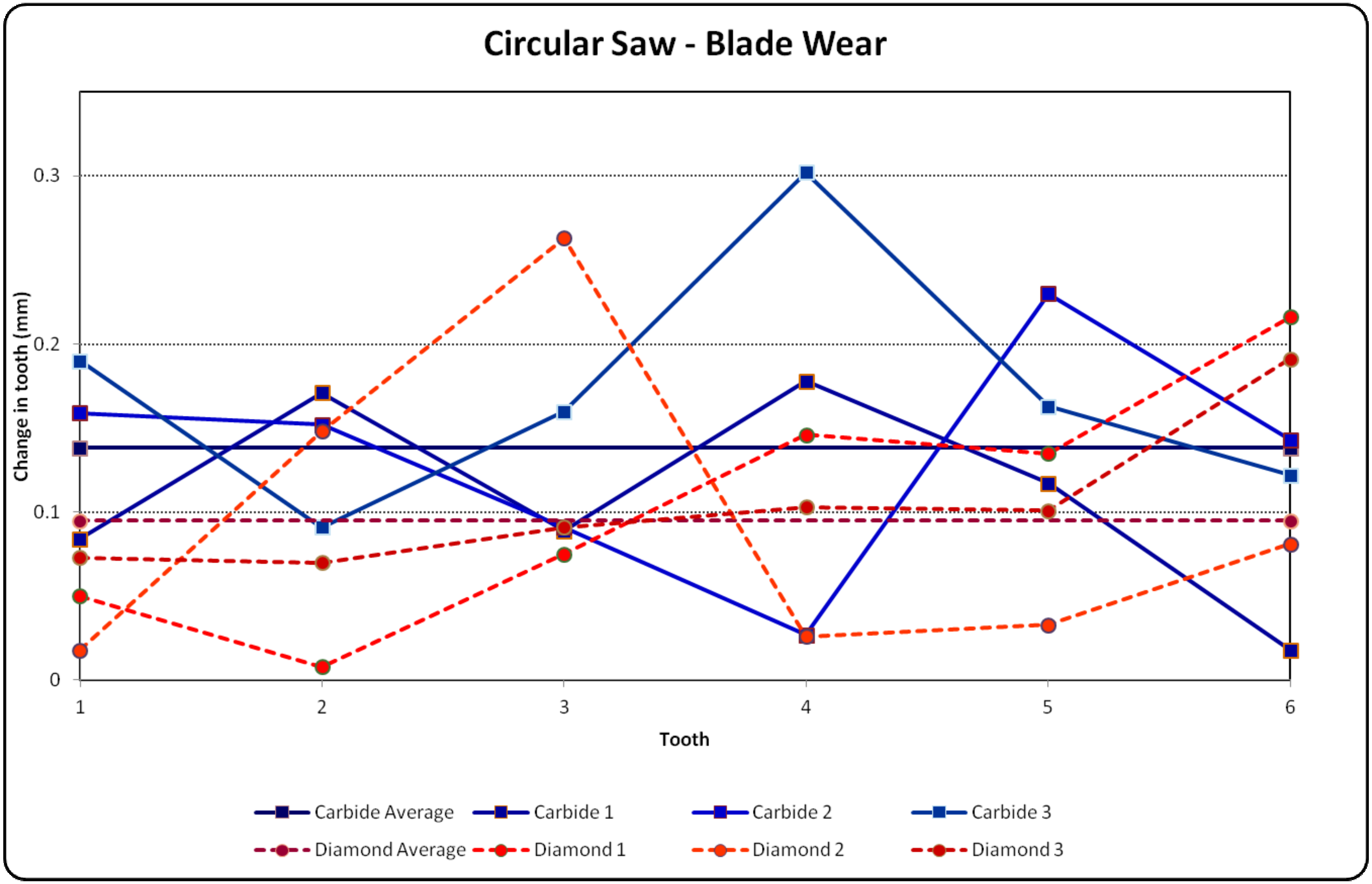
- Circular Saw
- Reciprocating Saw
- Hole Cutting Saw
- Pyrolance

Results



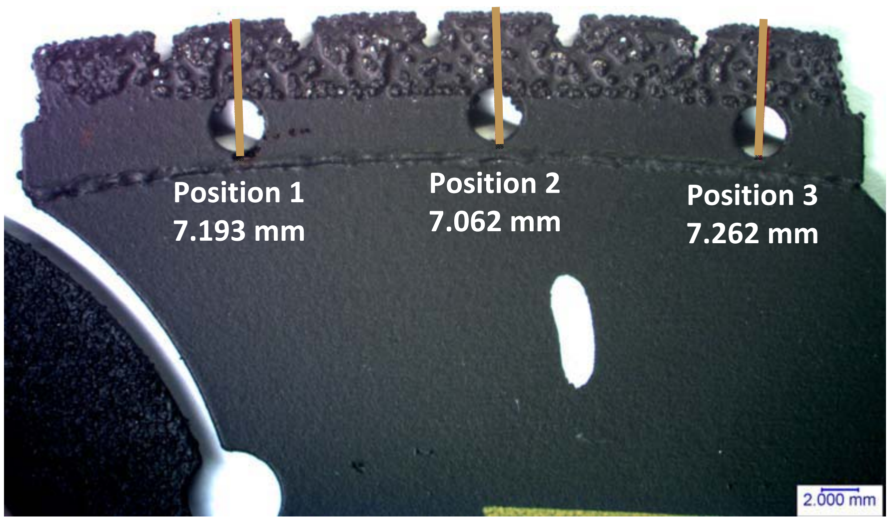
Diamond blade still sharp and capable of cutting additional materials. Carbide blades were dull and could not cut more than two sheets. Each sheet represented 127 linear feet of cutting.

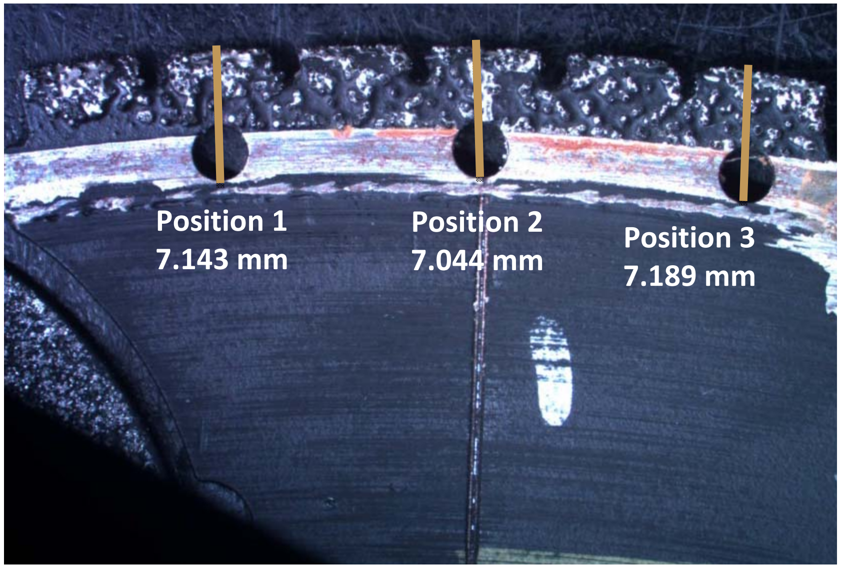
Results



Circular Saw - Blade Wear
Change in tooth (mm)
0.3
0.2
0.1
0
1
2
3
4
5
6
Tooth
Carbide Average
Carbide 1
Carbide 2
Carbide 3
Diamond Average
Diamond 1
Diamond 2
Diamond 3

Circular Saw Blade Teeth Before and After Cutting





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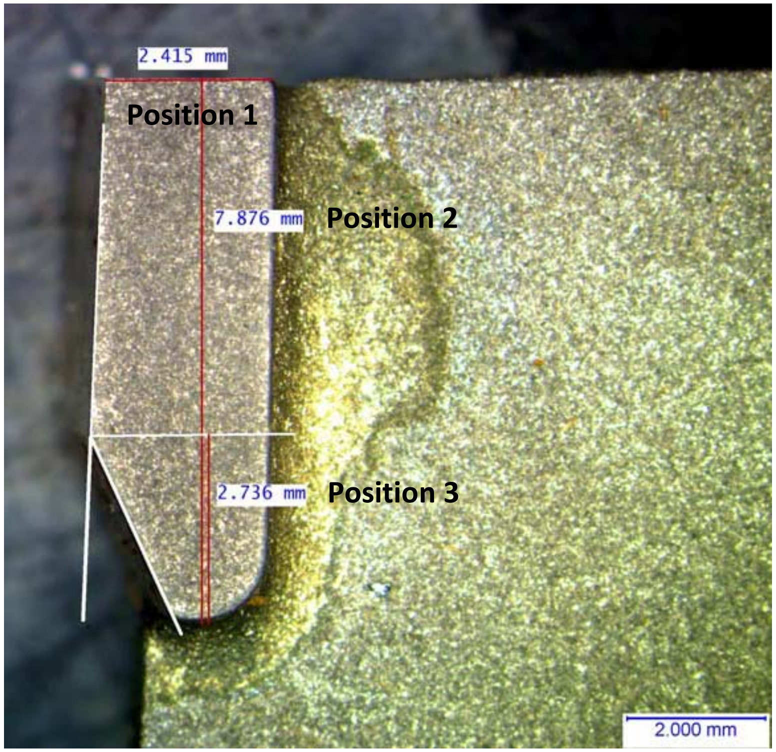
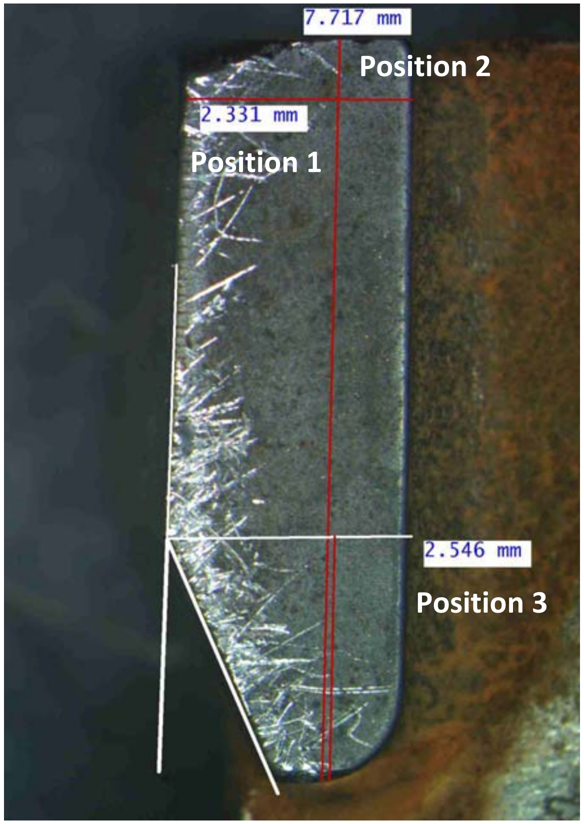




Typical

Objective IV

- **Determine and quantify contaminants to PPE from composite fires**
  - Soot and fugitive fibers expected
  - Contamination to bunker clothing, helmets, visors, respirators and other firefighting equipment
- **Determine cleaning techniques to decontaminate equipment and return to service**
  - Washdown, vacuum cleaning, wipes
  - Determine cleaning efficiency
  - Evaluate cleaned surfaces for re-use

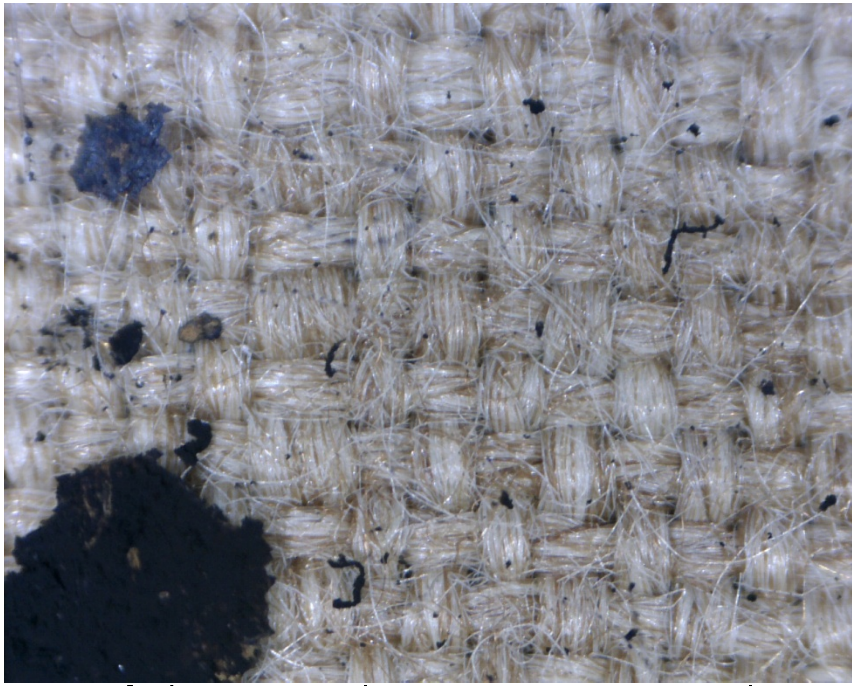
Technical Approach

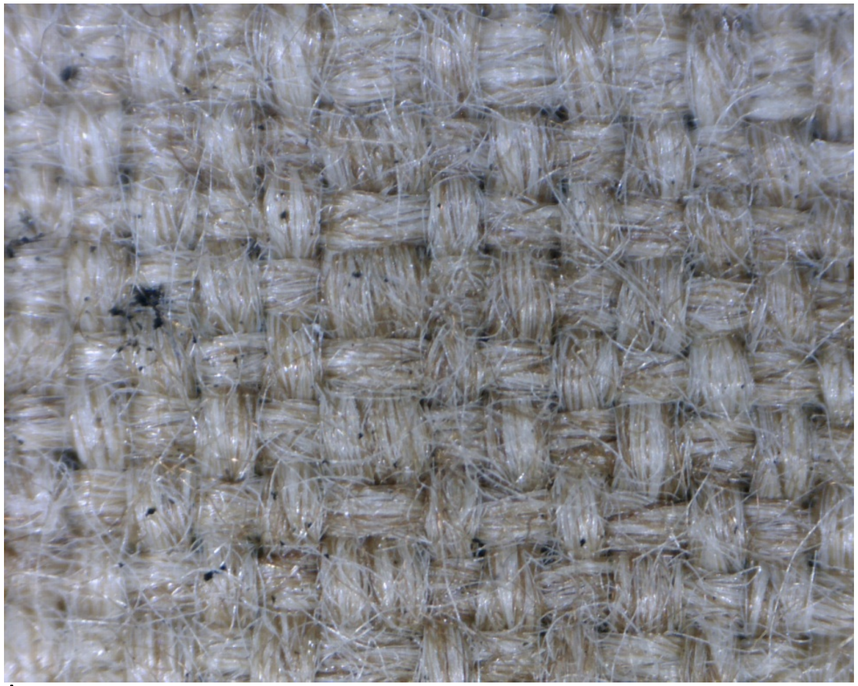
- **Prepare clothing coupons, respirators, helmets and other representative PPE "substrates"**
- **Expose substrates to composite fires – contaminate the substrates**
- **Measure contamination**
  – Photomicrography for particles and fibers
  – Measure foreign object number and surface area coverage
- **Clean and re-measure contamination**
  – Candidate cleaning techniques: Vacuum cleaning, wipes, washdown (water, water + detergent)
  – Combination cleaning techniques

Preliminary Results

Post-fire Bunker Coupon

Bunker Coupon After Vacuum Cleaning





•Use of a low-powered microscope-camera to photograph coupons
•Particles counted by MATLAB image analysis toolbox
  •Must convert color image to greyscale and then select a threshold to select smoke particles from other image fe
  •Image analysis toolbox can count “objects” and calculate relative areas
  •The seleected threshold must distinguish soot from weave holes etc.

Future Efforts

- All program items will be complete in the May – June timeframe
- New efforts are coming in the areas of composite fire mechanisms