Improvements in Surface Preparation Methods for Adhesive Bonding

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# Improvements in Surface Preparation Methods for Adhesive Bonding

## Summary

Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.

## Abstract

Details of the improvements in surface preparation methods for adhesive bonding are presented in this report. The focus is on enhancing the bond strength and durability of composite materials used in aerospace applications.

## Report Contact Information

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## Distribution/Availability Statement

Approved for public release; distribution unlimited

## Security Classification

- Report: Unclassified
- Abstract: Unclassified
- This Page: Unclassified

## Limitation of Abstract

Same as Report (SAR)

## Number of Pages

21
The purpose of this project is to:

• Demonstrate and validate the laboratory-verified, sol-gel processes developed under SERDP PP-1113 by addressing implementation issues for aluminum, titanium, and steel substrates utilized by tri-service aircraft platforms at the repair (depot and field) and OEM levels.

Dual Use Technology Development
DEMONSTRATION/VALIDATION OF SOL-GEL SURFACE PREPARATION FOR METAL ADHESIVE BONDING

Team Participants

- **USAF AFRL/MLSA**  Mr. Jim Mazza
- **Naval Air Systems Command, Pax River**  Mr. Matt Tillman
- **US Army TACOM-ARDEC**  Mr. Bill De Piero
- **USAF WR-ALC/LBRE**  Mr. Jay Fiebig
- **USAF WR-ALC/EN**  Mr. Bill Schweinberg
- **NAVAIR-NADEP Jacksonville**  Dr. Don Knapp
- **NAVAIR-NADEP Cherry Point**  Mr. Bill Alexander
- **NAVAIR-NADEP North Island**  Mr. Doug Perl
- **US Coast Guard**  LCDR Werner Winz
- **The Boeing Company**  Dr. Kay Blohowiak
- **Advanced Chemistry & Technology**  Mr. Stephane Pyrek
Environmental Reduction Targets

- **Aluminum**
  - Pasa-Jell 105
    - Hexavalent Chromium, Sulfuric Acid, Contaminated Waste Water
  - FPL Etch
    - Hexavalent Chromium, Sulfuric Acid, Contaminated Waste Water
- **Titanium**
  - Chromic Acid Anodizing
    - Hexavalent Chromium, Hydrofluoric Acid, Contaminated Waste Water
  - Phosphate Fluoride Etch
    - Hydrofluoric Acid, Phosphoric Acid, Contaminated Waste Water
  - Pasa-Jell 107
    - Hexavalent Chromium, Chromic Acid, Nitric Acid, Hydrofluorosilicic Acid, Contaminated Waste Water
- **Steel**
  - Ferric Chloride/Hydrochloric Acid Etch
    - Hydrochloric Acid, Sulfuric Acid, Contaminated Waste Water
- Tailorable to different resin/paint chemistries
- Robust process conditions
- Greater range of properties using inorganic and hybrid polymers than current state-of-the-art systems
Repair vs. OEM

Why we repair…

• Typically better controls at manufacturing level
  • Environmental controls
  • QC/inspection methods
• Fewer tools/materials available in field
• Training/certification
• New clean parts vs. dirty old parts
• Access to repair area
• Potential damage to areas adjacent to repair
**Sol-Gel Process Conditions**

- **Mix AC-130 sol-gel kit**
  - Induction time: 30 min
- **Clean and deox Al alloy surface**
- **Use specified sanding tools**
- **Brush or spray apply sol-gel**
- **Dry 30 min**
- **Spray apply BR6747-1**
- **Cure with heat**
Surface Treatment Comparison

Grit blast treatment prior to sol-gel gives a comparable result to PAA pretreatment, but is more difficult than manual abrasion in field repair applications.
WR-ALC TESTING

THERMAL SHOCK

FATIGUE

STATIC STRESS DURABILITY
Examples of Repair Implementations

- **C-5 Applications:**
  - Flaps, Ailerons, Engine Pylon Panels, Floorboards, Torque Deck, Fuselage, Bulkheads, Ramps
  - Depot Level, Off-Aircraft Repair

- **V-22 Al Repairs**

- **F-18 Al and Ti Repairs**

- **F-16 Al Repairs**

- **CH-46 and CH-47 Ti and Al:**
  - Rotor blade caps, erosion strips, underfloor corrosion repairs

- **B-1 Stainless Repair**

- **C-130 Al Repairs**

- **F-22 Ti Repairs**
OEM Sol-Gel Non-Cr Conversion Coatings

Boeing Technology

Boegel-EPII

Painting

AC-131*

Aluminum

Ti, Stainless, Ni, etc

XBMS 10-128
BSMS-25-002

BAC 5663
D6-1816

BAC 5665
BSPS-07-002

Bonding

AC-130*

Aluminum

Ti, Stainless, Ni, etc

XBMS 5-162
BSMS-25-001

SRM
51-70-10
51-70-09

BSPS-07-001
XBAC 5667

*AC-130 and AC-131 are products of AC Technology, Costa Mesa, CA, 2nd source supplier qualification currently in-work (Henkel, Socomor, PPG)
# Qualification Test Matrix

Boeing Technology

<table>
<thead>
<tr>
<th>TEST</th>
<th>TEST METHOD</th>
<th>TEST PROCEDURE</th>
<th>No. of Specimens*</th>
<th>MINIMUM REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lap Shear at 75 ± 5°F</td>
<td>BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>4200 psi</td>
</tr>
<tr>
<td>Lap Shear at -67 ± 2°F</td>
<td>BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>4200 psi</td>
</tr>
<tr>
<td>Lap Shear at 180 ± 5°F</td>
<td>BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>3100 psi</td>
</tr>
<tr>
<td>Lap Shear at 250 ± 5°F</td>
<td>BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>650 psi</td>
</tr>
<tr>
<td>Lap Shear at 75 ± 5°F after 30 days at 120 ± 5°F and 100% Relative Humidity</td>
<td>BSS7211 BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>4200 psi</td>
</tr>
<tr>
<td>Lap Shear at 75 ± 5°F after 30 days salt spray exposure at 95 ± 5°F</td>
<td>BSS7210 BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>3100 psi</td>
</tr>
<tr>
<td>Lap Shear at 75 ± 5°F after 7 days immersion in Jet A fuel at 75 ± 5°F</td>
<td>BSS7212 BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>4200 psi</td>
</tr>
<tr>
<td>Lap Shear at 75 ± 5°F after 7 days immersion in Reference Fuel B at 75 ± 5°F</td>
<td>BSS7212 BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>4200 psi</td>
</tr>
<tr>
<td>Lap Shear at 75 ± 5°F after 7 days immersion in BMS3-11 at 150 ± 5°F</td>
<td>BSS7212 BSS7202</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>4200 psi</td>
</tr>
<tr>
<td>Lap Fatigue at 75 ± 5°F</td>
<td>BSS7201</td>
<td>BSS7202 Type IIIA</td>
<td>3</td>
<td>10⁷ cycles at 1500 psi</td>
</tr>
<tr>
<td>Sustained Stress Loading at 140 ± 5°F and 100% Relative Humidity</td>
<td>BSS7209</td>
<td>BSS7202 Type V</td>
<td>10</td>
<td>90 days at 900 psi</td>
</tr>
<tr>
<td>Metal to Metal Climbing Drum Peel</td>
<td>BSS7206</td>
<td>BSS7206 Type II</td>
<td>10</td>
<td>25 lbf/in width</td>
</tr>
<tr>
<td>Wedge Crack after 7 days at 140 ± 5°F and 95% Relative Humidity</td>
<td>BSS7202</td>
<td>ASTM D3762</td>
<td>10</td>
<td>&lt;0.25 inch crack growth &gt;90% cohesive failure</td>
</tr>
</tbody>
</table>

*per batch for three batches for qualification
Sol-Gel Process Steps

Clean and prep surface to be treated

Class 1: Chemical
Class 2: Mechanical
Class 3: Mech/Chem

Prepare sol-gel coating solution (AC-130)

30 minute induction time
10 hour pot life

Apply sol-gel coating solution
Method 1: Spray
Method 2: Brush

Bond with Adhesive

Apply & cure bond primer (BR6747-1)

Dry/cure sol-gel coating solution

24 hours maximum elapsed time

24 hours maximum elapsed time

60 minute air dry minimum or 30 minutes air dry + 30 minutes @ 140°F

60 month storage
• Added as an option to SRM 51-70-09 and 51-70-10
  Implemented 2005-2006
  • Al 250F-cure repairs w/BMS 5-101
  • Al 350F-cure repairs w/BMS 5-137
  • Titanium repairs
• Only BMS 5-89 Ty II (Cytec BR 6747-1) allowed with Boegel-EPII
  • Compatibility of water-based product with sol-gel
• Goal: Replace HF/Alodine in fleet repairs
  • Health/Safety/Hazmat
  • Improved Durability
• Reduce process repair time/cost over anodize repair methods
• Uses specific abrasive materials and tools
• Robust process methods
Performance Comparisons

Boeing Technology

Lap Shear Testing

Wedge Crack Durability

24 hr exposure to 140°F/>98% RH

Larger is bad

DCB Extended Durability Tests

10-month Exposure at Long Beach Test Site

Force (in.-lb./in.²)
 Implemented in the Boeing Commercial Structural Repair Manuals in 2005
  - Metalbond Working Group
    - Airlines, Boeing R&D, Service Engineering, DERs

 Aluminum 250F repairs first
  - Added 350F Al repairs
  - Added Ti repairs

 Feedback from airline users good
  - Cost savings
  - Process robustness
  - Wanted some improvements
Boegel-EPII for Al Bonding Updates

- Added new sandpaper alternatives for use in Al bonded repairs
  - 3M 361F, 300D, 777F, 900DZ
  - Merit ALO Resin Bond
- Incorporated 2-part Boegel kits (AC-130-2) into BCA SRMs
  - More stable shelf-life
  - Easier shipping to overseas locations
  - More robust, easier to use
  - Equivalent performance and durability
- Working on draft BMS/BAC for internal OEM Al bonding applications
- Testing new nonchromated adhesive bond primers
  - Cytec BR6747-1NC
  - Cytec BR6700-1 (sol-gel compatible)
  - Initial data promising
Future Work – Deoxidation Methods

• Alternatives to Abrasive Deoxidation Methods
  • Improve robustness of process
  • Reproducibility over larger areas
  • Evaluate energetic techniques
    – Plasma
    – Laser
Future Work – Bond Primer

• Non-Chromated Adhesive Bond Primers
  • Preliminary data on 3M and Cytec candidates
  • Compatibility with Multiple Surface Prep Methods
    – PAA
    – Sol-Gel
  • Corrosion Protection within Bondline and Outside of Bondline
• Non-Aluminum Applications
  – Want one primer for all
• Industry Team
  – March Telecon; Spring 2008 SAMPE meeting
  – Contact kay.y.blohowiak@boeing.com to get on the distribution list for participation
Future Work – Other Bonded System Improvements

• Composites bonding
  • Reduce haz/mats used

• Improved Adhesive Systems
  • Improved durability – longer life