Kinetic Metallization™

Dimensional Restoration of Mg and Al Alloy Components & IVD Aluminum Repairs

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Overview

- Aerospace Repair Applications
- Kinetic Metallization (KM) Process
- KM - Portable and Production Systems
- Al-Trans® Powder Alloy Properties
- Qualification and Deployment of KM Repairs
  - IVD-Al and Alumiplate coatings on high-strength steels
  - Dimensional restoration of Mg & Al Alloy Components
  - Repairs of F-18 Aircraft Mounted Accessory Drive (AMAD) Gearbox Housing
- Summary of Applications
Problem - Repair of Damaged IVD Aluminum & Alumiplate Coatings

- HSS - Landing Gear & Components
  - Problem - Brush plating Cd or Ni-Zn
  - Environmentally sustainable repair
  - Opportunity - Al spray coating
  - Repair damaged IVD-Al coatings
  - Alumiplate coating repairs
- Naval Aviation FRC & IMF
  - F/A-18, E-6B, H-1, V-22, F-35
Aircraft - Dimensional Restoration
Mg and Al Alloy Components

- Transmission Gearboxes, Housings, Generators
  - Fixed Wing Aircraft (F/A-18, P-3, F-35)
  - Rotary Aircraft (AH-64, AH-1W, AH-1Z, CH-53, HH-1N, MH-53E, SH-60, UH-60)
- Mg Alloys (AZ80A, AZ91C, AZ91E, ZE41, AEZ33A, WE43B-T6, AZ92-T6, HC32A-T5, QE22A-T6)
- Al Alloys (356, 357, 6061, 7050, 7075)
Dimensional Restoration Repairs of Worn Landing Gear Struts

- Dimensional Restoration of Cylindrical Bores
  - Bore internal diameters 3-inches (80-mm)
  - Bore Depths of 48-inches
- Air Force Depot Facilities at Tinker & Hill AFB
- F-16 Fighting Falcon
Introduction to Kinetic Metallization™ (KM)

- Metal deposition through particle impact
- Low-temperature << melting point
- **Sonic Mach 1 Nozzle**
  - High particle velocity > 750 m/s
  - Pressure < 1 MPa (150 psig)
  - Temperatures to 450 °C
  - Powder preheater & mixer
  - Powder injection at nozzle inlet
  - Low noise < 75 dBA @ 1 m
  - High quality coatings
Kinetic Metallization™ Difference

Gas Storage System

Ultra-fine Powder Fluidizing Unit

2.5 kW Thermal Conditioning Unit < 150 psig

Powder

Heat

Sonic Deposition Nozzle with Powder Preheater & Mixer

Kinetic Energy

Mass Loading ~ 100% gas mass flow
KM-Mobile Coating System (KM-MCS)

- KM-Mobile Coating System
- Handheld KM Spray Gun
- Brush-sieve powder fluidizing units
- Integrated subsystems on cart
- Applicable Coatings (e.g.)
  - Air/GN2 (Al-Trans®, Cu, Zn, Ni)
  - He/GN2 (WC-Co, Ni alloys, Nb, Ta)
  - Composite polymers (PEEK, PTFE)

Al-Trans® = Aluminum + Transition Metal, Oxide, or Ceramic 2nd Phase
KM-Production Coating System (KM-PCS with Robot)

- Robotic KM Spray Gun
- Repairs of large surfaces
- Uniform coating thickness
- Gas blending (He, GN2 or Air)

Applicable Coatings
- Air/GN2 (Al-Trans®, Cu, Zn, Ni)
- He/GN2 (WC-Co, Ni alloys, Nb, Ta)
- Composite polymers (PEEK, PTFE)

Powder Loading
- ~100% gas mass flow

Cold Spray limited to 5% gas mass flow
KM-Guns Dimensional or Coating Repairs

- **KM-Standard Gun**
  - Robotic rastering & translation
  - Uniform & large area coating repairs

- **KM-Handheld Gun**
  - Lightweight (< 5 lbs)
  - Round or oval nozzles (< 75 dBA)
  - Preheated powder chamber
  - Gas blending (He, GN2 or Air)

- **KM-ID Gun**
  - Bore internal diameters 3-inches (80-mm)
  - Bore Depths ~ 48-inches
Al-Trans® IVD Aluminum Repairs

- **Surface Preparation**
  - Removable of topcoat, primer, & IVD Al with bristle disk abrasion
  - Masking of repair area with aluminum tape to protect border areas
- **Al-Trans® Coating Properties on High Strength Steels**
  - Adhesion of > 10 ksi without de-lamination
  - Coating protection >3000 hrs in salt fog per ASTM B117
  - Superior corrosion protection in SO2 salt fog per ASTM-G85
  - Passed Joint Test Protocol-2003 specifications
<table>
<thead>
<tr>
<th>KM Repair Sequence for IVD-Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVD-Al Removed</td>
</tr>
<tr>
<td>Feather Edges</td>
</tr>
<tr>
<td>KM Al-Trans® Repair</td>
</tr>
</tbody>
</table>
Al-Trans®
Corrosion Protection
IVD-Al Repairs

- Composite Al-Trans® Powder
- Properties
  - Hardness HRB = 62
  - Porosity < 0.5%
  - Corrosion - Salt Fog B117
    - 3000 Hrs
    - Substrate 4130 steel
F-18 Axle
IVD-Al Repair
KM Al-Trans® Coating
## Al-Trans® Kinetic Metallization
### JTP-2003 Qualification Tests

<table>
<thead>
<tr>
<th>Reparability Test</th>
<th>JTP</th>
<th>Acceptance Criteria</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unscribed Salt Fog</td>
<td>3.3.1, 3.7.1</td>
<td>3000 Hrs ASTM B117-94</td>
<td>Pass</td>
</tr>
<tr>
<td>Scribed Salt Fog</td>
<td>3.3.2, 3.7.1</td>
<td>1000 Hrs ASTM B117 94</td>
<td>Pass</td>
</tr>
<tr>
<td>Unscribed SO2 Salt Fog</td>
<td>4.1.1</td>
<td>500 Hrs ASTM G85</td>
<td>Pass</td>
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<tr>
<td>Scribed SO2 Salt Fog</td>
<td>4.1.2</td>
<td>500 Hrs ASTM G85</td>
<td>Pass</td>
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<tr>
<td>Unscribed Salt Fog</td>
<td>3.1.4</td>
<td>3000 Hrs ASTM B117-94</td>
<td>Pass</td>
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</tbody>
</table>
Scribed Salt Fog Testing
ASTM B-117
Scribed Cyclic SO$_2$ Salt Fog (ASTM G85 annex 4, B117/SO$_2$)

**Brush Cd** Repair Specimens  
168 Hours

**KM Al-Trans®** Repair Specimens  
504 Hours
<table>
<thead>
<tr>
<th>Reparability Test</th>
<th>JTP</th>
<th>Acceptance Criteria</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Embrittlement</td>
<td>3.6.1</td>
<td>200 Hr/75% ASTM F519</td>
<td>Pass</td>
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<tr>
<td></td>
<td>3.7.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen Re-Embrittlement</td>
<td>3.6.1</td>
<td>200 Hr/75% ASTM F519</td>
<td>Pass</td>
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<tr>
<td></td>
<td>3.7.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion Resistance 14 Fluids</td>
<td>3.3.4</td>
<td>No Coat Degradation Compared to Brush Cd</td>
<td>Pass</td>
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<tr>
<td>Stress Corrosion Cracking</td>
<td>4.3</td>
<td>SEM Fractography</td>
<td>Pass</td>
</tr>
<tr>
<td>Scribed Painted Coating</td>
<td>3.3.5</td>
<td>3000 Hrs ASTM B117 - 94</td>
<td>Pass</td>
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</tbody>
</table>
KM Dimensional Restoration Repairs

- KM Portable System
  - Handheld KM Spray Gun
- Aircraft Alloy Components
  - Gearboxes & transmissions
    - Al-357 Cast
    - Mg ZE41A
  - Al-alloy stanchions & hinges
Dimensional Restoration Repairs

Surface Preparation
- Clean surfaces to remove oils/grease
- Grit blast surfaces to remove oxidation and debris in casting pores

Al-Trans® Coating Properties
- Al-Trans® coating formulation selected for component alloy application
- Adhesion of > 10 ksi
- Coating protection >3000 hrs in Salt Fog per ASTM B117
- Hardness > HRB 62
## Al-Trans® Powder Alloy Properties

### Dimensional Restoration

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
<th>CP-Al Al-Trans</th>
<th>6061-Al Al-Trans</th>
<th>7075Al Al-Trans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>&gt; 62 HRB</td>
<td>62 HRB</td>
<td>63 HRB</td>
<td>100 HRB</td>
</tr>
<tr>
<td>Interface/Coating Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
</tr>
<tr>
<td>Bond Strength</td>
<td>&gt; 10 ksi</td>
<td>&gt; 10 ksi</td>
<td>&gt; 10 ksi</td>
<td>&gt; 10 ksi</td>
</tr>
<tr>
<td>Porosity</td>
<td>&lt; 1%</td>
<td>&lt; 0.5%</td>
<td>&lt; 0.5%</td>
<td>&lt; 0.5%</td>
</tr>
</tbody>
</table>
7075 Al-Trans®
Dimensional Restoration Repairs

- Composite 7075Al-Trans® Powder
- Properties
  - Hardness HRB = 100
  - Porosity < 0.5%
  - Corrosion - Salt Fog B117 - 1000 hrs
Repair of F-18 Aircraft Mounted Accessory Drive (AMAD) Gearbox

- North Island Fleet Readiness Center
- AMAD 357Al cast housing damaged by gear failure
- Requires dimensional restoration of sealing surfaces, oil passages, hydraulic pads, and cast surfaces
KM Al-Trans® Repair of Fretted F-18 AMAD Hydraulic Pad
KM Al-Trans® Repair of Fretted F-18 AMAD Hydraulic Pad

Hydraulic pad surface, post KM spray

Hydraulic pad post machining
KM Al-Trans® Repair of Damaged Oil Passage Port on F-18 AMAD
Al-Trans® Dimensional Repairs on 7050-Al Notches (5-mm wide)

- KM Repair Process
- Handheld KM Gun of KM-MCS
- Properties
  - Hardness - HRB = 60-65
  - Porosity < 0.5%
  - Good bond with 7050-Al
Summary of Kinetic Metallization for IVD-Al and Dimensional Repairs

- KM IVD Aluminum Repairs with Al-Trans®
  - Kinetic Metallization enables repairs of IVD-Al & Alumiplate coatings on HSS
  - Al-Trans® coatings superior to Brush Cd for IVD Al repairs
  - Environmentally compliant

- KM Dimensional Restoration Repairs of Mg and Al Components
  - Applicable to damaged gearbox and transmission housings
  - Properties can be tailored by Al-Trans® formulation
  - Reduces maintenance cost to ~1/10 of replacement cost for housings
  - Reduces repair schedule from weeks/months to days
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