



Kinetic Metallization™

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

AeroMat 2011 Session 1 - Novel Manufacturing

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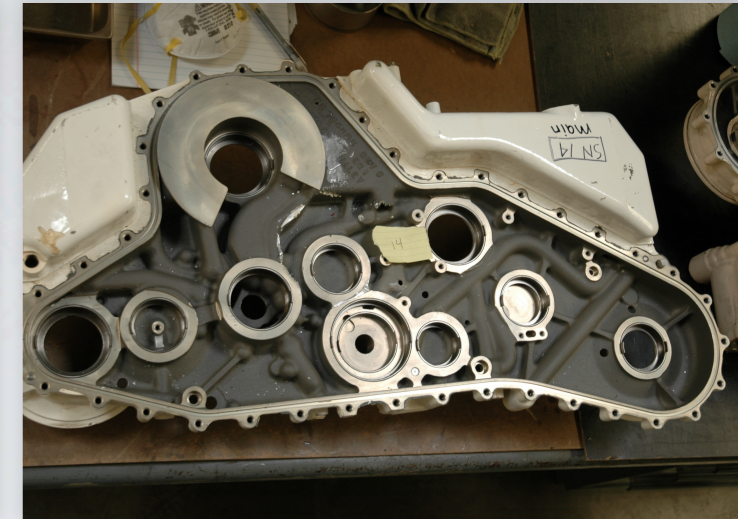
Overview

- 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 Alumiplaate 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)

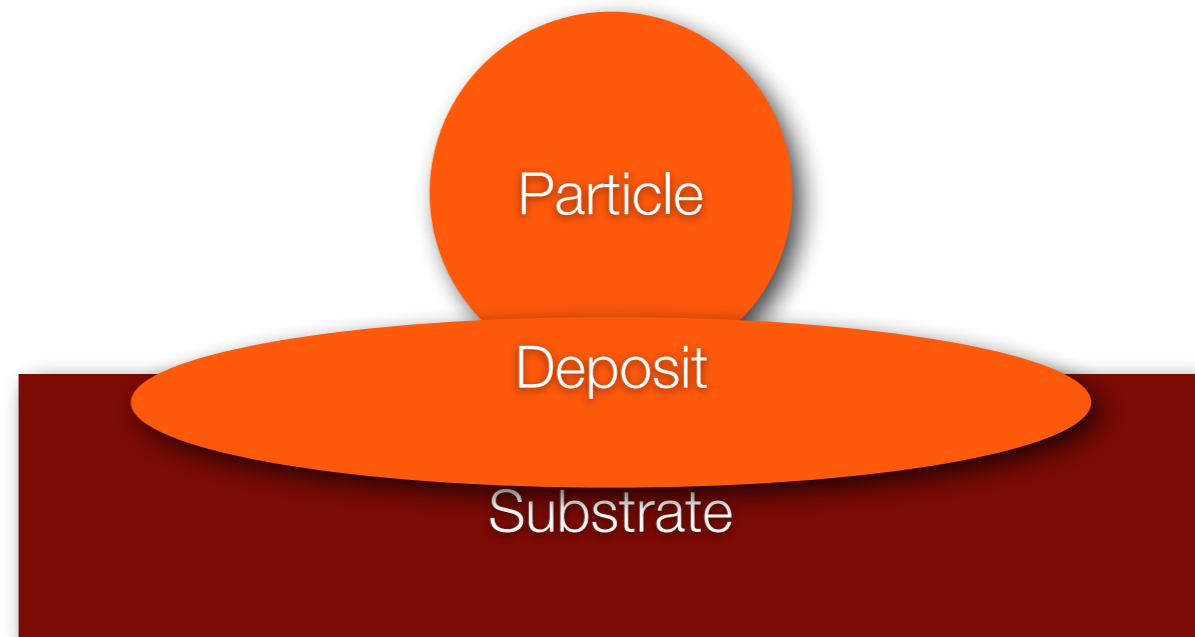


Dimensional Restoration Repairs of Worn Landing Gear Struts

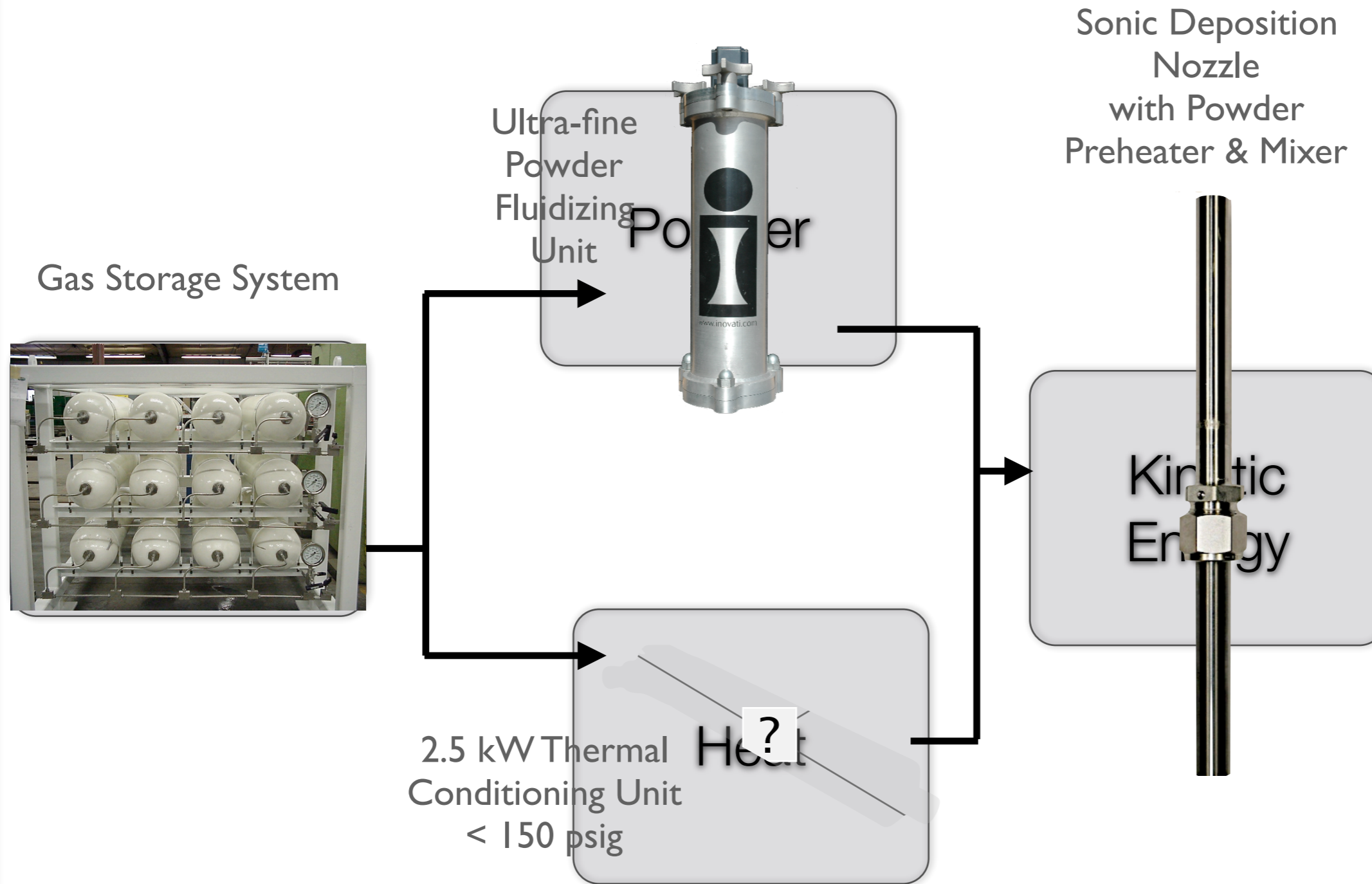
- Dimensional Restoration of Cylindrical Bores
 - Bore internal diameters 3-inches (80-mm)
 - Bore Depths of 48-inches
- Air Force Depot Facilities at Tinker & Hill AFB
 - F-16 Fighting Falcon

Introduction to Kinetic Metallization™ (KM)

- Metal deposition through particle impact
- Low-temperature \ll 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



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)



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





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



KM Repair Sequence for IVD-AI

IVD-AI Removed

Feather Edges

KM AI-Trans[®] Repair

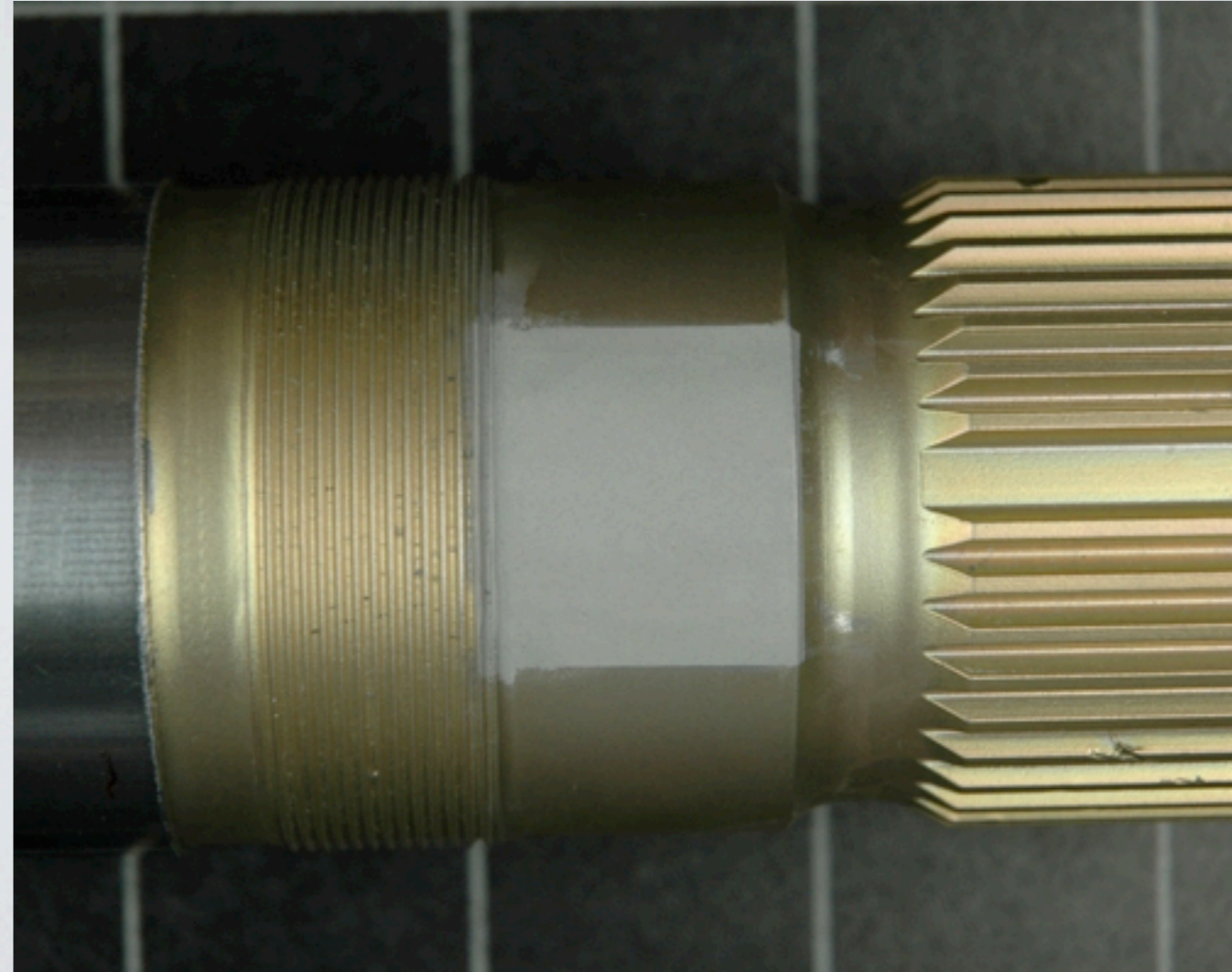
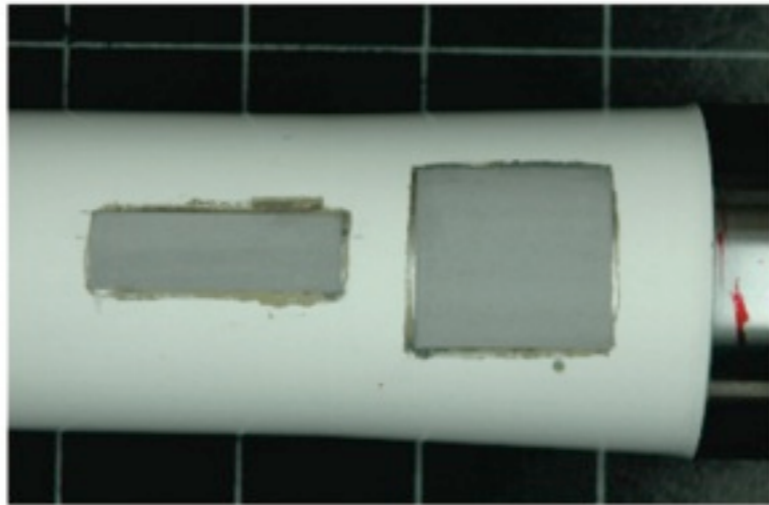
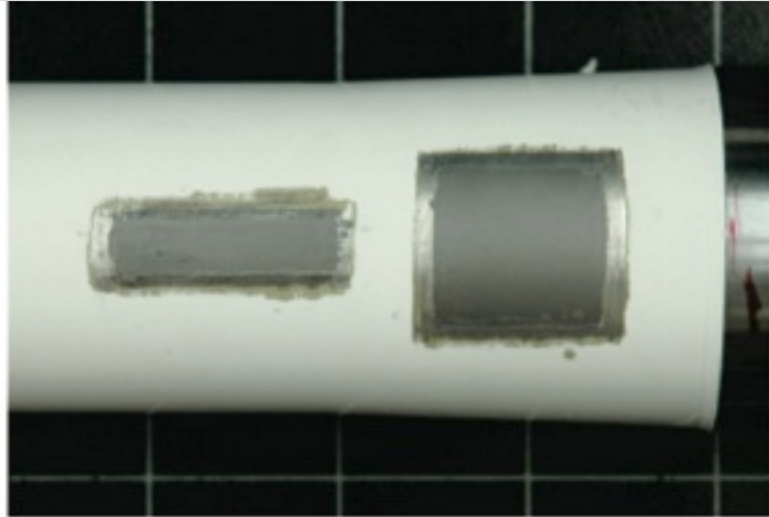


Al-Trans®

Corrosion Protection

IVD-AI 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-AI Repair
KM Al-Trans[®] Coating

Al-Trans[®] Kinetic Metallization JTP-2003 Qualification Tests

Reparability Test	JTP	Acceptance Criteria	Pass/Fail
Unscribed Salt Fog	3.3.1 3.7.1	3000 Hrs ASTM B117-94	Pass
Scribed Salt Fog	3.3.2 3.7.1	1000 Hrs ASTM B117 94	Pass
Unscribed SO2 Salt Fog	4.1.1	500 Hrs ASTM G85	Pass
Scribed SO2 Salt Fog	4.1.2	500 Hrs ASTM G85	Pass
Unscribed Salt Fog	3.1.4	3000 Hr ASTM B117-94	Pass



Brush Cd control specimens

KM Al-Trans[®] repair specimens

Scribed Salt Fog Testing ASTM B-117



Brush Cd Repair Specimens
168 Hours

KM Al-Trans® Repair Specimens
504 Hours

Scribed Cyclic SO₂ Salt Fog
(ASTM G85 annex 4, B117/SO₂)

Al-Trans[®] Kinetic Metallization JTP-2003 Qualification Tests (cont')

Reparability Test	JTP	Acceptance Criteria	Pass/Fail
Hydrogen Embrittlement	3.6.1 3.7.1	200 Hr/75% ASTM F519	Pass
Hydrogen Re-Embrittlement	3.6.1 3.7.1	200 Hr/75% ASTM F519	Pass
Corrosion Resistance 14 Fluids	3.3.4	No Coat Degradation Compared to Brush Cd	Pass
Stress Corrosion Cracking	4.3	SEM Fractography	Pass
Scribed Painted Coating	3.3.5	3000 Hrs ASTM B117 - 94	Pass

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

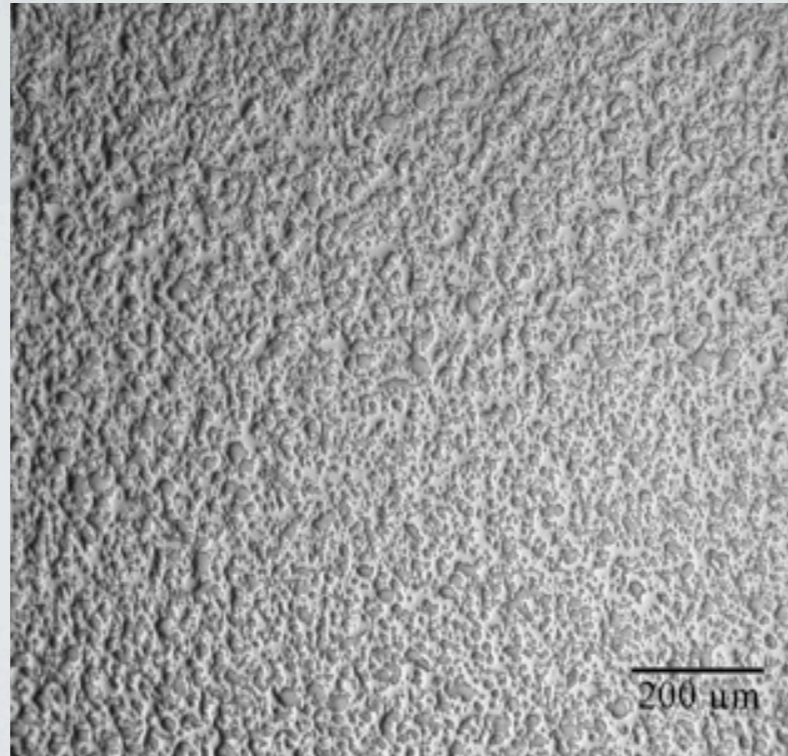
■ Al-Trans® Coating Properties

- 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

Property	Requirement	CP-Al Al-Trans	6061-Al Al-Trans	7075Al Al-Trans
Hardness	> 62 HRB	62 HRB	63 HRB	100 HRB
Interface/Coating Cracks	No Cracks	No Cracks	No Cracks	No Cracks
Bond Strength	> 10 ksi	> 10 ksi	> 10 ksi	> 10 ksi
Porosity	< 1%	< 0.5%	< 0.5%	< 0.5%

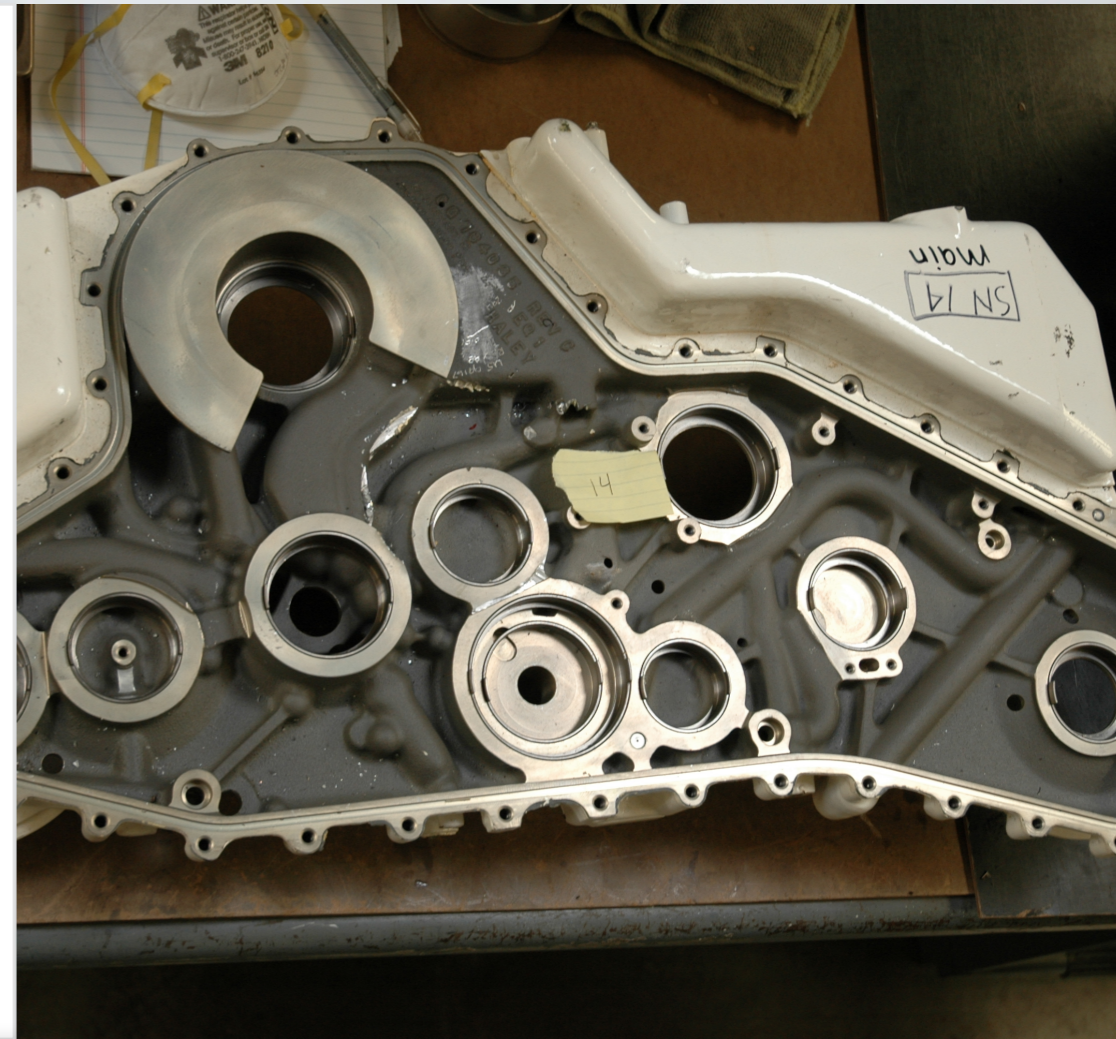


7075 Al-Trans® Dimensional Restoration Repairs

- Composite 7075Al-Trans® Powder
- Properties
 - Hardness HRB = 100
 - Porosity < 0.5%
 - Corrosion - Salt Fog B117 - 1000 hrs

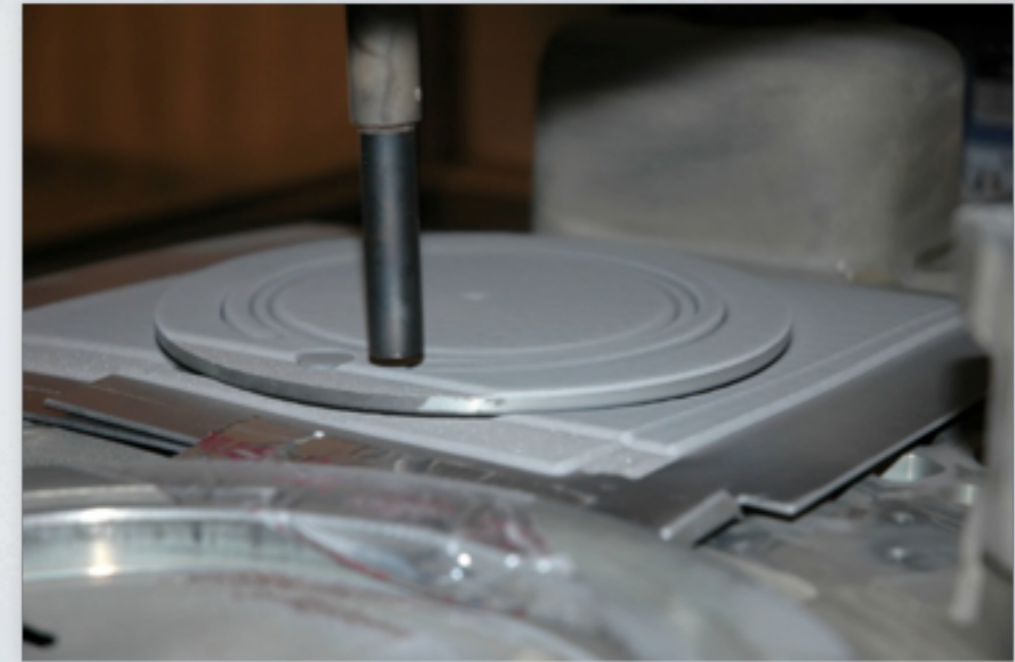
Repair of F-18 Aircraft Mounted Accessory Drive (AMAD) Gearbox

- 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





Severely fretted AMAD hydraulic pad



KM repair of AMAD in spray cabinet

**KM AI-Trans® Repair of Fretted
F-18 AMAD Hydraulic Pad**



Hydraulic pad surface, post KM spray



Hydraulic pad post machining

KM Al-Trans® Repair of Fretted F-18 AMAD Hydraulic Pad

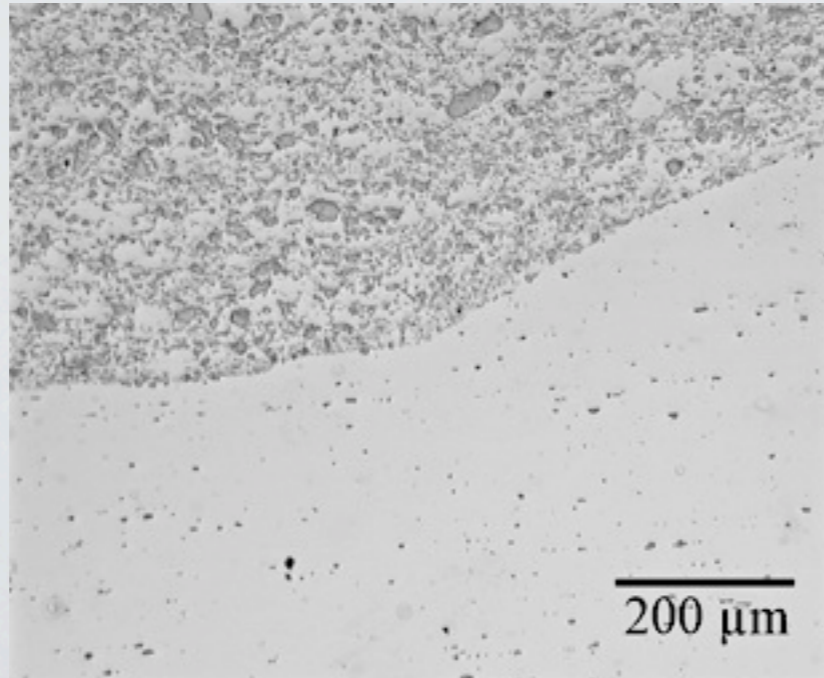
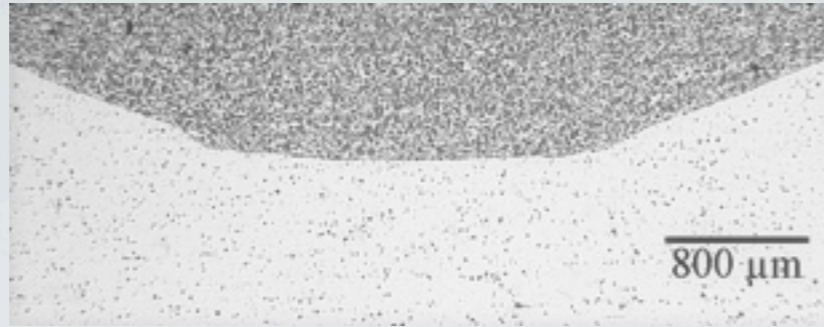


Damaged Oil Port with Al Plug



KM Restoration Prior to Final 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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