Frame 6 Users Group Conference

Coatings for Industrial Gas Turbines

Praxair Surface Technologies, Inc.
Indianapolis, IN
Houston, TX, Charlotte, NC
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Sanibel Island, FL
Overview

Turbine Coatings

Combustor Coatings

Compressor Coatings
Compressor Coatings
Compressor Coatings

- Bell mouth:
  Air inlet coated with SermeTel Air Dry Epoxy Coating System
Compressor Coatings

• Casing refurbishment capability:
  › No diffusion layer therefore no base material loss.
  › Mild chemical stripping solution required to remove coatings therefore no risk of attack to base metal.
  › Parts can be restored to “as new” condition.

Casing “as received”  Casing after refurbishment
Compressor Coatings

- **Metallic-Ceramic Coatings:**
  - Erosion, Corrosion and oxidation resistant
  - Fouling and chemical resistant
  - Improve surface finish significantly
  - Increase compressor efficiency
  - Environmentally friendly
  - Chrome Free
  - Cad Replacement
Compressor Coatings
SermeTel® System 5380DP®

- < 25 µin Ra (.030” cutoff)
- > 2000 hr scribed in salt fog
- Thin inorganic barrier
- Sacrificial, Densely Packed aluminum-ceramic primer
- 8000+ psi bond
- Stable at pH 4 to 8
- Stable to 1050F (566C) in continuous operation
- No mechanical polishing

Specifications:
- DL 2062-27, 83342NU – Siemens
- GE – F50TF62, PWA 110, RR
- Solar, GE IGT, etc
SermeTel 5380DP

SermeTel base coats can be sealed with ceramic and/or organic topcoats, as well as paints to provide corrosion barrier coatings, with extended life.

- Thin inorganic barrier
- Sacrificial aluminum/ceramic primer
- Base Material
Compressor Coatings

- **Mobile compressor coatings:**
  - Eliminates de-blading and re-blading
  - Coat compressors at customer site
  - Reduces overhaul cycle time & cost
  - Coating prevents corrosion & fouling
  - Customers are power generation plants (OEM involvement)
Compressor Coatings

• Efficiency Gains:
  › Quantified Payback Measured on Two (2) Sister W501F’s at FP&L.
  › Compressor Efficiency Increase 0.64%
  › Coating Payback in Less Than Three (3) Months
  › Some operators report 2-4% Efficiency increases

[Graph showing compressor efficiency comparison over time]

DATA TAKEN AT HIGH LOADS ONLY
NO LOSS IN COMPRESSOR EFFICIENCY NOTED
Compressor Coatings

• **SermaLon:**
  Antifouling coating with Non-stick organic barrier to reduce Fouling caused by:-

  › Inorganic Fouling
    - Formation of corrosion products
drying/deposit of dissolved minerals
electrostatic deposition

  › Organic Fouling
    - Polymerization of hydrocarbons
deposition of tars, carbonaceous deposits

![Graph showing efficiency over months with SermaLon and No coating](image)
Compressor Coatings

Centrifugal Compressor Rotor and Statics coated with SermaLon
SermaLon

Multi-layer organic/inorganic coating

- Non-stick organic barrier
- Inhibiting organic film
- Sacrificial aluminum/ceramic primer

Physical Properties

- Typical Thickness Range: 0.004-0.006 inches (100-150 μm)
- Maximum Continuous Operating Temperature: 500°F (260°C)
- Peak Operating Temperature/Time: 600°F (315°C)/1 hour
- pH Operating Range: 3-9

- 8000+ psi bond
- < 40 μin RA (.030” cutoff)
- Stable at pH 3 to 9
- Stable to 500°F (260°C)
Advanced Compressor Coatings

- Compressor Erosion:
  - Inlet water fogging systems increase power, however blades can be damaged by Liquid Droplet Erosion.
  - Typical attack on the leading edge

- Advanced TiN Coatings can help control or eliminate this damage

- Both laboratory and field testing (7FA)
Titanium Nitride – Type II

- Water jet laboratory testing was used to select the best TiN type coating for field testing.

- PST’s selected two 24K TiN Coatings:
  - 24K Type II multilayer coating
  - 24K Type IV multilayer TiN w/compliant Ti Layers

- 7FA 30,000 hour field test results confirmed lab testing
  - 24K Type II showed minimal degradation

- Estimated life of the 24K Type II coating is > 50,000 hours
Compressor Coatings

- **Chrome Free Coatings:**
  - Driven by
    - Hazardous Material Regulations
    - RoHS
    - WEEE (electronics)
    - ELV (automotive)
    - REACH
  - Worker Safety Regulations
    - OSHA TLV
  - Industry Efforts
    - OEM Programs
    - Military - Industrial Consortia
  - Chrome 6+ free base and sealer coats.
  - No performance deficit compared to traditional SermeTel.

<table>
<thead>
<tr>
<th>Chrome containing Praxair Coating</th>
<th>Equivalent Chrome (VI) Free</th>
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<tbody>
<tr>
<td>SermeTel W</td>
<td>SermeTel 7100</td>
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<tr>
<td>SermaSeal 570A</td>
<td>SermaSeal 7700</td>
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<tr>
<td>SermeTel W + 570A</td>
<td>SermeTel 7725</td>
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</table>
Thermal Barrier Coatings

MCrAlY (Metal + CrAlY) Bond coat
Ceramic top coat
Hot Section Coating Evolution

TBC’s

Increased turbine temperatures (°F)

-100 0 0 100 200 300 400 500 600


Bond Coats
MCrAlY’s Aluminides

EBPVD
DVC
Multi-layer
Low k
SPS
HP DVC
EBC + CMC?

NextGen MCrAlY++ Aluminide +

Low Density

Low Density

DVC

DVC

EBPVD

EBPVD

Muti-layer

Muti-layer

Low k

Low k

Low k

SPS

SPS

SPS

EBC + CMC?

EBC + CMC?

NextGen MCrAlY++ Aluminide +

NextGen MCrAlY++ Aluminide +

APS

APS

Shrouded APS

Shrouded APS

Tribomet

Tribomet

HV OF

HV OF

LPPS

LPPS
Bond Coat Selection

Powder Chemistry

- APS
- HVOF
- Shrouded APS
- LPPS

Coating Process

Chemistry and Coating Process are your Key Decisions

Land/aero-based engine applications

Marine-based engine applications
Thermal Sprayed MCrAlY

Dual layer CoNiCrAlY, by Shrouded Plasma process

Single layer CoNiCrAlY bondcoat, by HVOF process
Microstructure of TBCs

- **Erosion Resistance**
  - APS Abradable
    - 30-40% porosity
  - APS Low density
    - 10-30% porosity
  - Zircoat® - DVC
    - 10% porosity ~ 20 Cracks/cm
  - EBPVD
    - Columnar Structure

- **Strain Tolerance - Thermal Shock Resistance**
  - Suspension Plasma Spray
    - Columnar Structure
  - Low k with APS 8YSZ inter layer and shroud plasma bondcoat

Suspension Plasma Spray
- Columnar Structure
Dense Vertically Cracked Thermal Barriers

- **Zircoat DVC – Thermal Barriers**
  - Improved Toughness over Low Density
  - 3X to 4X the erosion resistance of low density
  - Greater thermal strain tolerance due to vertical cracks
  - Greater thickness capability up to 0.100”
  - ~2X higher thermal conductivity

- **Applications:**
  - Blades, Vanes, Ring Segments
  - Combustors, Transitions, Shrouds, fuel nozzles

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**Erosion Rate (mg/g)**

- LZ-16 DVC
  - 50 micron angular Al₂O₃, 200 Ft/sec, 25° C, 20° Angle of Impingement
  - 3X+ higher erosion resistance

**JETS – Thermal Shock Test**

- % Cracking on OD vs. Temperature C°
  - LZ-45 (85%)
  - LZ-16 (91%)

**Furnace Cycles**

- 50Min @ 1135°C, 10 min Air Quench
  - Max
  - Min

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Low Density (85%) | Dense Vertical Cracked (91%)
Abradable/Abrasive Coatings
Heat shield Section

Common Areas to Coat
› Seal face
› Edges (some)

Solutions
› HVOF/plasma NiCrAlY, NiCoCrAlY, CoNiCrAlY
› Plasma abradables TBC (12-60 mils)
  – 30%-40% porosity

Features / Benefits
› Bondcoats (Corrosion & Oxidation)
› Topcoats (Thermal Protection and air tight)
Abrasive Tip Systems

● Zircoat
  › YSZ DVC –
  › OEM Approved Compressor and Turbine applications

● Tribomet
  › Entrapment plating process
  › “Traps” Abrasives in metal matrix (Ni or MCrAlY)
    – CBN, SiC, Al2O3, etc
  › Particles can be coarse or fine dependent on requirements and interaction with mating surfaces
  › OEM approved blade tip and seal applications
  › Tribomet can coat non line of sight surfaces (seal teeth)
Combustor Coatings

MCrAlY (Metal + CrAlY)

TBC (Thermal Barrier Coating)
Combustion Section

**Common Areas to Coat**
- Liners / Venturis / Transition Pieces
- Cowl Caps, Fuel Nozzles, X-Fire Tubes

**Solutions**
- NiCrAlY, NiCoCrAlY, CoNiCrAlY
- Low Density TBC (< 20 mils)
  - 5-20% and 15-25% porosity
- Higher Purity Low Density TBC
  - Up to 40 mils
- DVC (20-100 mils)

**Features / Benefits**
- Bondcoats (Corrosion & Oxidation)
- Topcoats (Thermal Protection)
Combustor Coatings

• End covers & caps:
  › Air Plasma Spray (APS)
  › MCrAlY & TBC
    - Reduce Metal Temperature
    - Reduce Cracking, Erosion and Burning
Combustor Coatings

• **Liners and Transition Pieces:**
  
  › APS Plasma spray

  › MCrAlY & TBC
    - Reduce Metal Temperature
    - Reduce Cracking and Burning

  › Chrome Carbide
    - Extend Life & Reduce Wear on Spring

  › Complex part geometry
Combustor Coatings

- Tiles and segment plates:
  - APS Plasma spray
  - MCrAlY & TBC
  - Chrome Carbide
Combustor Coatings

• Annular combustor:
  › APS Plasma spray
  › MCrAlY & TBC
  › Large capability to coat any size OEM parts and geometry
Combustor Coatings

- Hot gas casings:
  - APS Plasma spray
  - MCrAlY & TBC
  - Large capability to coat any size OEM parts and geometry
Turbine Coatings

MCrAlY (Metal + CrAlY)

TBC (Thermal Barrier Coating)
Turbine Coatings
Turbine Section

Common Areas to Coat
› Blades / Vanes / Shroud Tiles
› Rotors / Disk Restoration

Solutions
› SermaLoy J, SermAlcote, PtAl
› NiCrAlY, NiCoCrAlY, CoNiCrAlY
› Low Density TBC (< 20 mils)
  – 5-20% and 15-25% porosity
› Higher Purity Low Density TBC
  – Up to 40 mils
› DVC (20-100 mils)
› Restoration w/ Ni-Al plus SermeTel 2F-1

Features / Benefits
› Aluminides & Bondcoats
  – (Corrosion & Oxidation)
› Topcoats (Thermal Protection)
› Restoration

Ni-Al + SermeTel 2F-1
Blade and Vane Coating

- **MCrAlY Bond coats**
  - Low Pressure Plasma (LPPS),
  - Air Plasma Spray (APS)
  - High Velocity Oxy-Fuel (HVOF)

- **TBC Top coats**
  - Air Plasma Spray
  - Suspension Plasma Spray (SPS)
Challenges on Coating Characterization
Example 1: Metallography

A tale of two samples from the same coating!

Bond coat

Top coat
Example 2: Bond Cap Tensile Strength Test

ASTM C-633

Mating Cap
Adhesive
Coating
Bond Cap

Tensile Test Results (psi)

<table>
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<th>Run Number</th>
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Thank you.

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