Chromate Free Magnesium Gearbox Protection System

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Chromate Free Magnesium Gearbox Protection System

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Outline

- Magnesium: Why mag?
- Application
- Challenging Feature
- Legacy System
- Candidates
- New System
- Functional Requirements, Tests and Results
- Examples of Tests
- Benefits and conclusions
Why magnesium?

- Lightest of the structural metals
  - ¼ of steel
  - 1/3 of aluminum
- World production: ~400,000 ann
- No limit:
  - 8\textsuperscript{th} most common element
  - 6\textsuperscript{th} most abundant metal
  - Sea water contains ~0.15% mag
- Recycling requires only 5% OEM
- The BMW N52 (st6 dohc engine) crankcase shell since 2004. \textsuperscript{Ref 1}
- Since 1936, VW has used cast mag
Why protect magnesium?

Ref 4
Ref 5
Ref 6
Ref 7
Ref 8
Ref 9
Ref 10
The AE2100D3 engine

PGB – Propeller Gear Box
GMAD – Gearbox Mounted Accessory Drive
Split line illustration

Gearbox external surfaces

Gearbox split line

Gearbox internal oil zone

O-ring and O-ring groove
Legacy coating system

Oil Wetted Surfaces
Dichromate

Mount Material
"Dichromate" (AMS 2475)
Magnesium Base Metal

Split Lines / Machined Surfaces
Silicone Resin over HAE

Mount Material
Wi Resin
HAE
Magnesium Base Metal

External Cast Surfaces
Top Coat over HAE

Mount Material
Paint
HAE
Magnesium Base Metal

Mount Material
Silicone Resin
HAE
Magnesium
Legacy coating system

- HAE
  - Patented in 1952 (by Harry A. Evangelitis)
  - Corrosion resistance
  - Surface finish
- Complex masking scheme for application
- Regulatory pressures
  - Hexavalent Cr – sustainability issue
  - High VOC content in solvents

A comprehensive replacement of the legacy coating was needed

- Improved thickness consistency
- Improved unit cost
- Lessened environmental impact
- Improved corrosion performance and aftermarket cost
Proposed coating system

• Anodize
  o Tagnite 8200 Type 1 (AMS 2466)

• Paint
  o Indestructible Paint Ltd
    Chromate free Low VOC 985 series
      ▪ Sealer (green tinted)
      ▪ Primer
      ▪ Top Coat
Tagnite - What is it?

Chemical Composition as a Percentage of Water

- Tagnite: 5% chemical concentration
- HAE: 25% chemical concentration
- Dow 17: 56% chemical concentration

*Approximations

HAE contains heavy metals; Dow 17 contains heavy metals and chromium
Rockhard - What is it?
Proposed coating system

Internal Oil Wetted Surfaces
Sealer over Tagnite

Internal Oil Wetted Surfaces
Sealer over Tagnite

Split Line /Machined Surfaces
Top Coat, Primer & Sealer over Tagnite

Split Line /Machined Surfaces
Top Coat, Primer & Sealer over Tagnite

External Cast Surfaces
Top Coat, Primer & Sealer over Tagnite

External Cast Surfaces
Top Coat, Primer & Sealer over Tagnite

Mount Material

Mount Material

Rockhard Topcoat layers

Rockhard Topcoat layers

Rockhard Primer

Rockhard Primer

Rockhard Sealer

Rockhard Sealer

Tagnite

Tagnite

Magnesium Base Metal

Magnesium Base Metal
Side by side look at coating schemes
Functional Criteria, Tests and Results

- Coating Adhesion - PASS
  - ASTM D3359 Method B

- Corrosion Resistance - PASS
  - Cyclic Salt Spray:

- Thermal Stability (430°F, 1000 hrs) - PASS
  - ASTM D714

- Fluid Resistance (fuel, oil, hydraulic) - PASS
  - ISO 2812-1

- Damage Resistance (impact, bend, corner radii) - PASS
  - ASTM D2794, ASTM D522, Rolls-Royce Corp Test Method

- Releasability (Ease of Disassembly) - PASS w/ use of Frekote 700-NC
  - Rolls-Royce Corp Test Method (per IR 37340)

- Repairability (after damage and touch-up repair) - PASS w/ Brush Tagnite
  - Adhesion: ASTM D3359 Method B
  - Metallographic

- Fatigue Testing (bar) - PASS

- Torque Testing (scrap part) - PASS

- Engine Test (assembly/leak check) - PASS
Magnesium panels for environmental testing

Panel Type A:
- Anodize Coating Only

Panel Type B:
- Panel A plus Sealer

Panel Type C:
- Primer
- Clear Sealer
- Conversion Coat

Panel Type D:
- Primer
- Clear Sealer
- Conversion Coat
- Top Coat
Corrosion testing – anodize coatings

Panel Type A

Criteria: Coating shall receive a rating of 9 after exposure to 24 hours in neutral salt spray AND the new coating system shall meet or exceed the performance of the old coating configuration.

Result: Pass
Corrosion testing – external surfaces

Criteria: Coating shall receive a rating of 7 after exposure to 250 hours in neutral salt spray AND the new coating system shall meet or exceed the performance of the old coating configuration.

Result: Pass
Fluid Resistance

Rockhard Sealer - Panel Type B

Before | After
--- | ---

Rockhard Primer - Panel Type C

Before | After
--- | ---

Rockhard Top Coat - Panel Type D

Before | After
--- | ---

**Criteria:** All panels shall show no visual signs of blistering or lifting after exposure to fuel (Jet A) and hydraulic fluid (Royco 782).

**Results:** Pass

Fuel: 70°C, 163 hrs
Hydraulic Fluid: 70°C, 189 hrs
Impact damage resistance

Panel Type B

- Rockhard

Panel Type C

- Rockhard
- Legacy

Panel Type D

- Rockhard
- Legacy

Criteria: There shall be no cracking or detachment at an indentation depth of 3.8 mm (.15 inch) using a 1000±1 g punch AND the new coating system shall meet or exceed the performance of the old coating configuration.

Result: Pass
Fatigue performance

Criteria:
No increase in fatigue debit over legacy or baseline coating.

Result: Pass
Repair and Overhaul

- Plastic Media Blast removal process successful in removing the paint without removing the anodize

Criteria: The coating shall be strippable and be capable of supporting subsequent re-paint

Results: PASSES
Engine Test

• Purpose
  o Assembly/fit check
  o Leak check

• Testing details
  o Prop Stand test
  o Post-engine test inspection

• Results
  o After 3 tear downs and 150 hours
  o New coating configuration PASSES
Conclusion:

It’s in production!

- Performance improvement
- Environmental liability eliminated
- Unit Cost neutral
- Improvement in Aftermarket costs

Ref 1: http://www.magnesium-elektron.com/about-magnesium.asp?ID=1
Ref 2: www.intimag.org/showcase/mg001.pdf
Ref 4: http://www.fwtec.com/FW/nanosolution.html#
Ref 5: Rolls-Royce Front Frame example
Ref 6: http://www.volksworld.com/blog/staff-blogs/jons-blog/stripping-down-a-donor-beetle-engine/
Ref 7: http://www.corrosionist.com/galvanic_corrosion_chart.htm
Ref 8: http://airandspace.si.edu/webimages/highres/5013h.jpg
Ref 9: Corrosion and Materials, Vol 30 No 6, 2005 ISSN 1326-193

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Questions?