HCAT Progress Report
January 2007

Ben Evans
Materials and Process Technology
Goodrich Landing Gear

CONDUCTING THREE FULL SCALE TESTS:

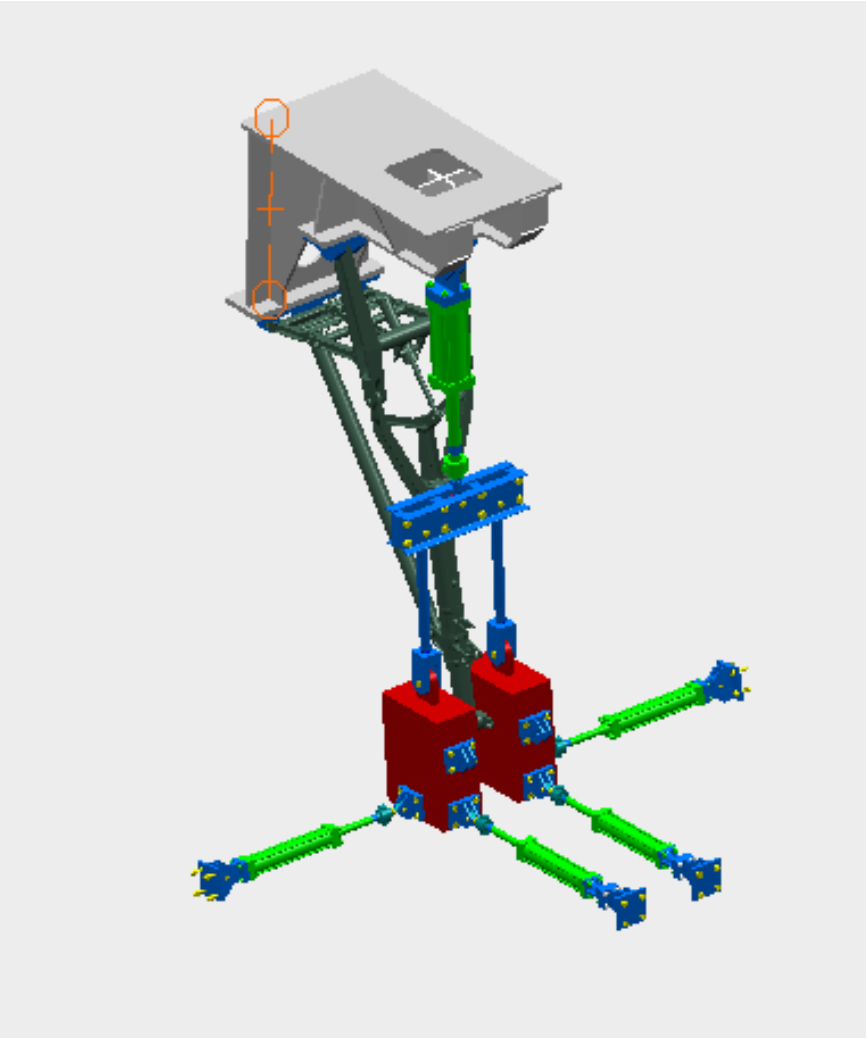
1. Fatigue of entire MLG - Dash-8 Series 400.
Complete
2. High Cycle (Dithering) wear test on hydraulic actuator.
Complete
3. Fatigue of MLG pistons 5” and 10” OD (Cr vs. WC-Co-Cr). 66% complete

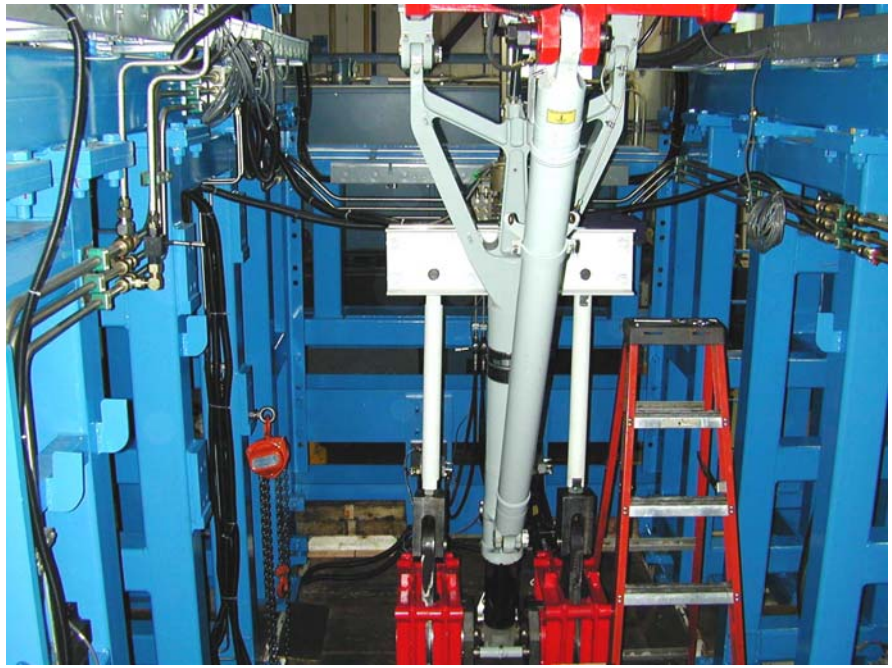
HVOF coating for test 1 and 3 is WC-Co-Cr.
HVOF coating for test 2 is WC-Co

Test 1 Status

Fatigue of Entire MLG - Dash-8 Series 400.

Test 1 Status





TEST 1: MLG FATIGUE TEST

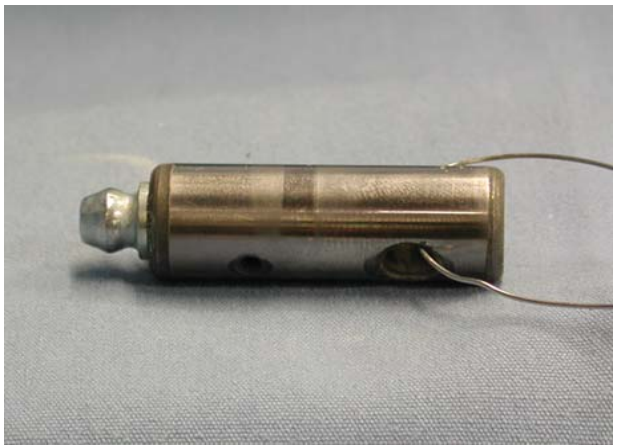
- 14 parts have been HVOF coated (piston, axle, and pins).
- The testing requires 10 layer of testing, each layer includes 32 blocks of test conditions (load location, magnitude, direction and number of cycles).
- Testing considered successful when the gear withstands 5 lives of fatigue loads without initiation of detectable fatigue cracks. 1st life inspection revealed no issues.
- Gear has completed the required 5 lives of testing.

Test 1 Status

- Pins showed some “shadowing” from the mating parts but no measureable wear.
- No cracks, chips, spalls, etc. were noted.
- All pins were acceptable.

Test 1 Status

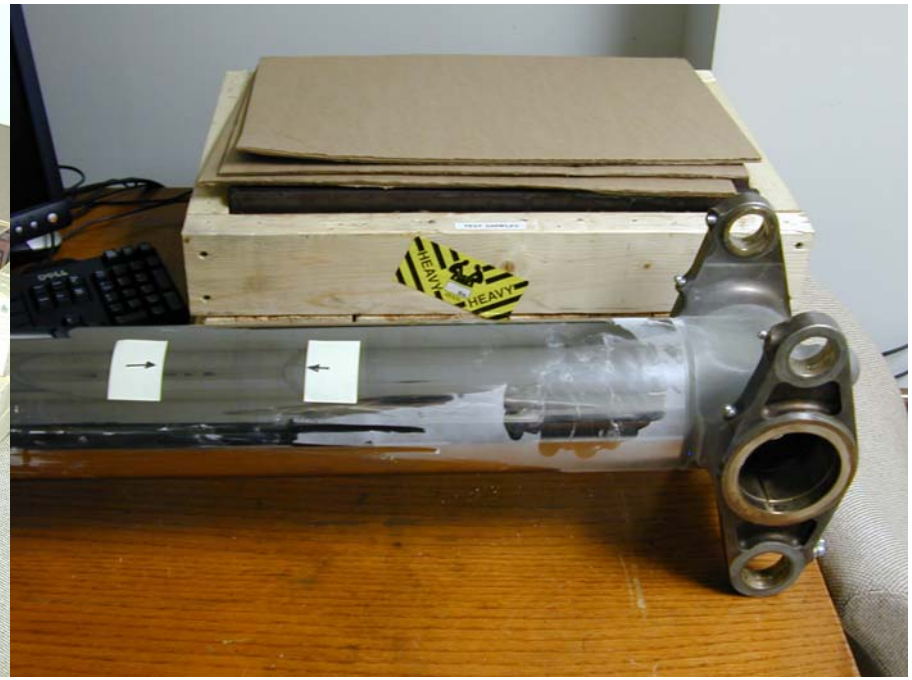
Dash 8 Pins After 2 Lives of Fatigue Testing



Test 1 Status

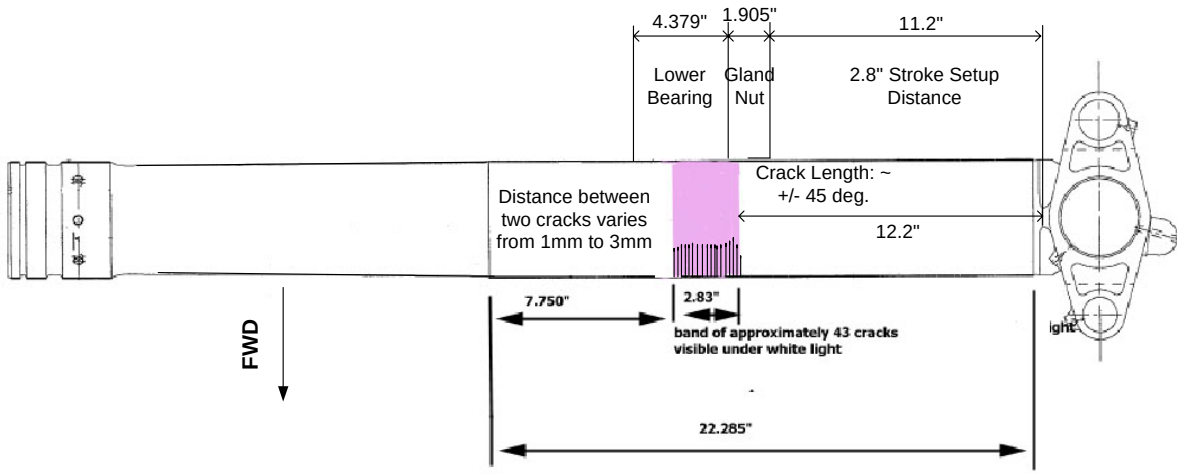
Dash 8 Pins After 5 Lives of Fatigue Testing

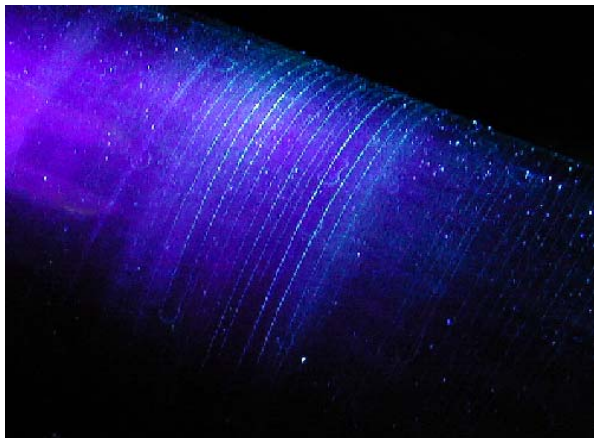
Test 1 Status



Previously cracks were observed in the HVOF coating after 2 lives of testing.

Test 1 Status





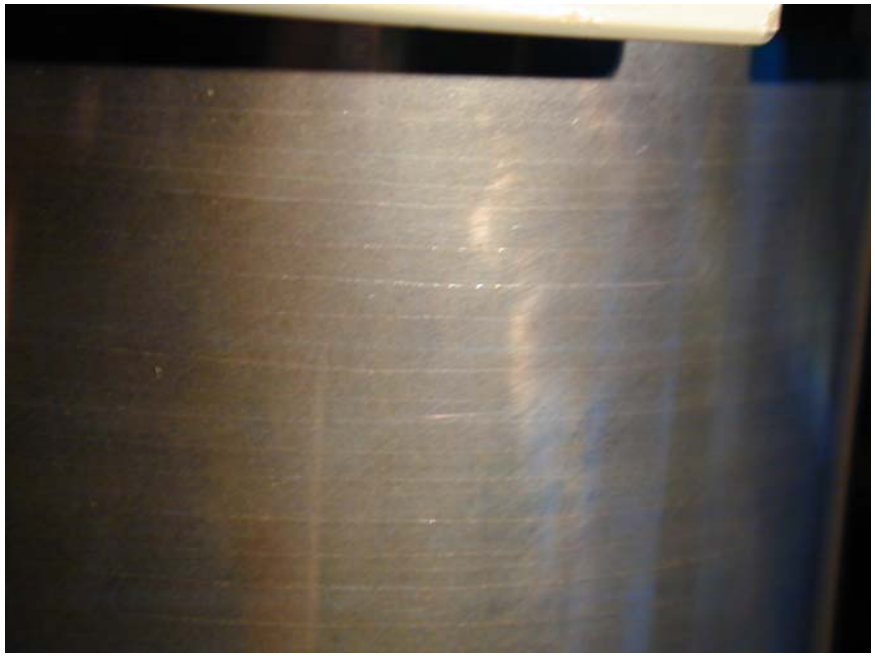
Test 1 Status

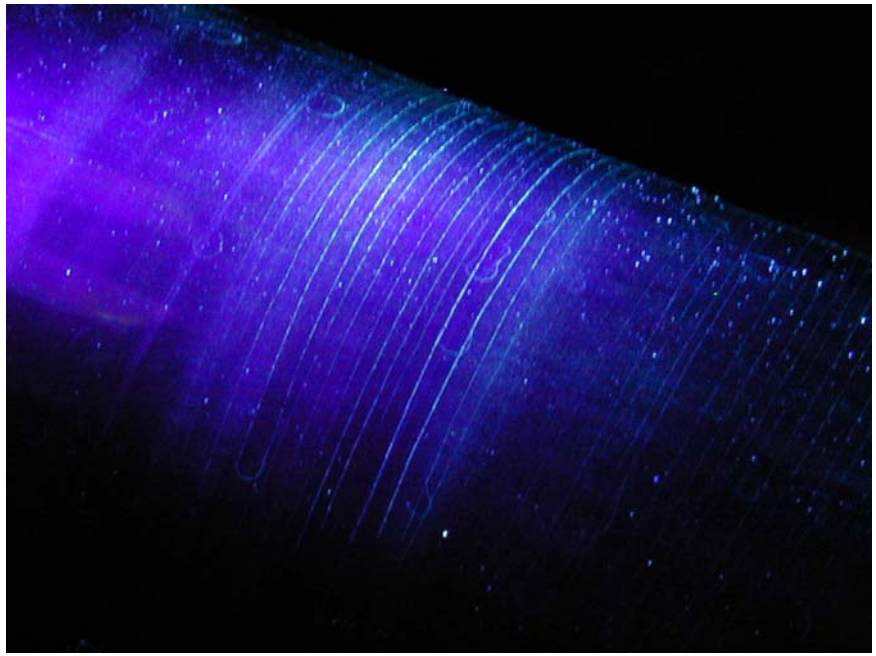
- **STATUS – NOV. 2003**

- After 2.5 lives of testing microcracks could be “felt” with fingernail, and were visible by eye

- Continued testing in identical conditions

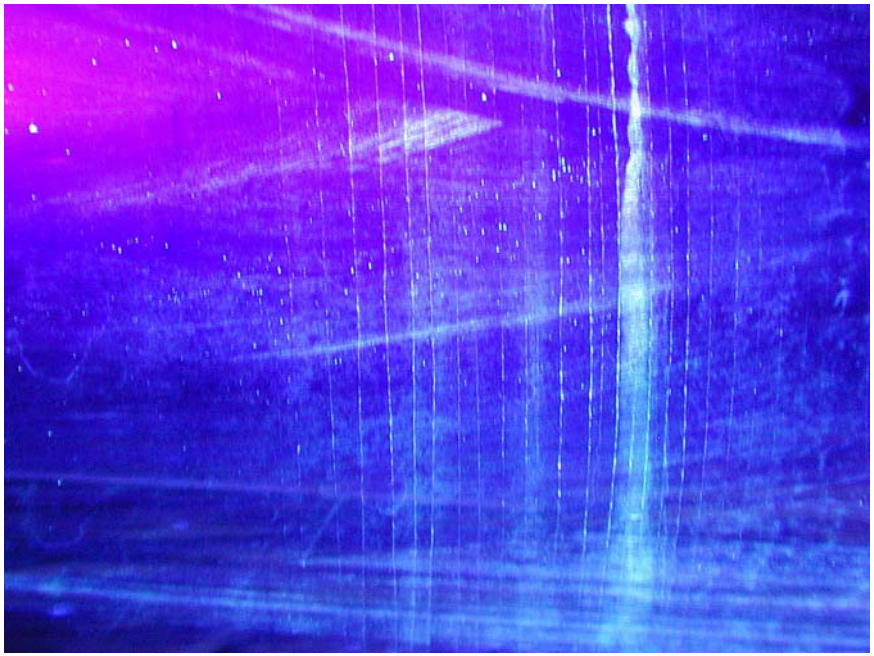
Test 1 Status





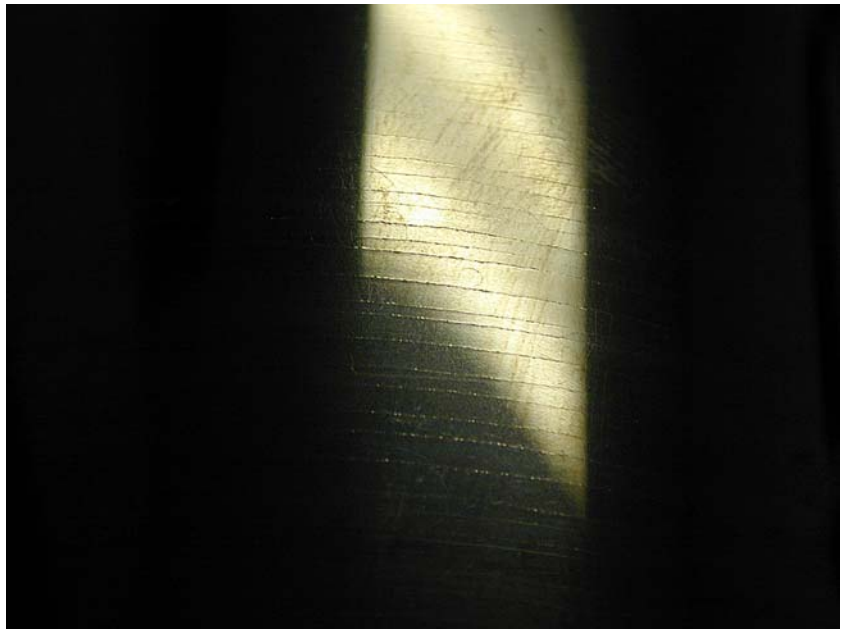
Cracks in piston coating observed after 2.5 lives of testing. After 3 lives the cracks are virtually the same: no evidence of more cracks or the cracks significantly growing.

Introduction



Cracks in piston coating observed after 5 lives of testing. After 5 lives the cracks showed increased fraying on the edges and were more detectable by the finger nail test.

Test 1 Status



The piston was Barkhausen noise (rollscan) and no damage to the substrate was detected.

Test 1 Status

- **ANALYSIS**

- Location of cracks corresponds with the 2.8” stroke, and highest spectrum loads:

Outer Fiber Stress	Cycles
177ksi to -122ksi	150 cycles
159ksi to -110ksi	300 cycles
142ksi to -98ksi	450 cycles
125ksi to -85ksi	2500 cycles

- Stress levels on Dash-8S400 spectrum quite high compared to other aircraft (including A380-WLG, BLG)

Test 1 Status

- **QUESTIONS – WAY FORWARD**

- Is microcracking a functional concern? Depends on seal design and stress levels. Elastomeric seals are more forgiving than PTFE cap seals.

    - Cracks appeared after two lives,
    - Major overhauls after ~1/3 -1/2 life,
    - Not uncommon to strip and re-chrome pistons at major overhaul

- Will the HVOF eventually spall? Is corrosion an issue?
- What is the threshold for the onset of cracking?

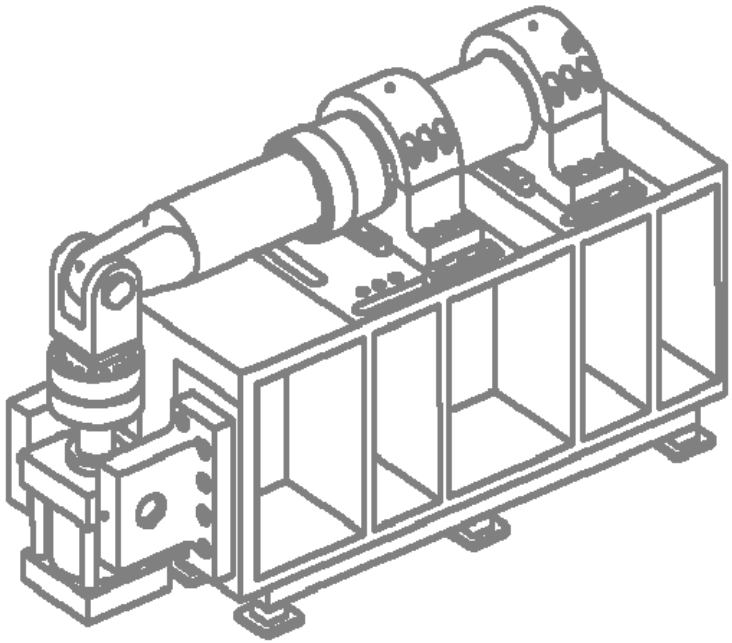
Test 1 Status

- Testing considered successful when the gear withstands 5 lives of fatigue loads without initiation of detectable fatigue cracks.
- Test result is acceptable.

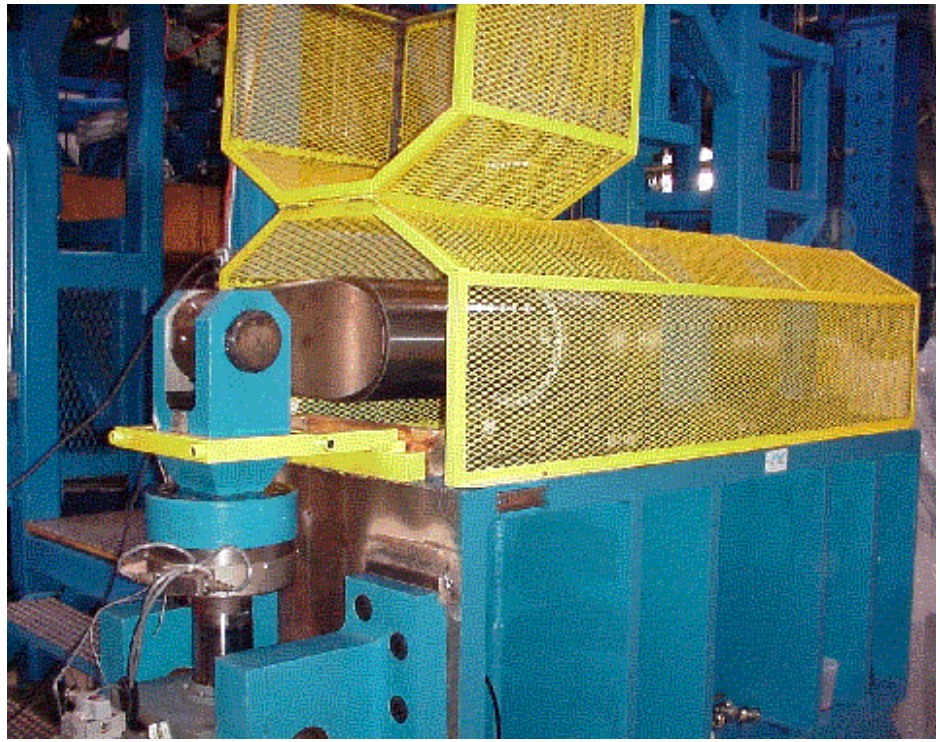
Test 3 Status

Fatigue of MLG pistons 5” and 10” OD (Cr vs. WC-Co-Cr)

Test 3 Status



ISOMETRIC VIEW



Test 3 Status

- **Test Conditions**
- Bending loads based on fatigue analysis and landing gear fatigue requirements.
- Bending stresses approx. 100 ksi at R= -1.
- 50,000 cycles = 1 block of tests. Inspection after every block.
- Expected lives: 285,000 for 5” pistons, 330,000 for 10” pistons.

Test 3 Status

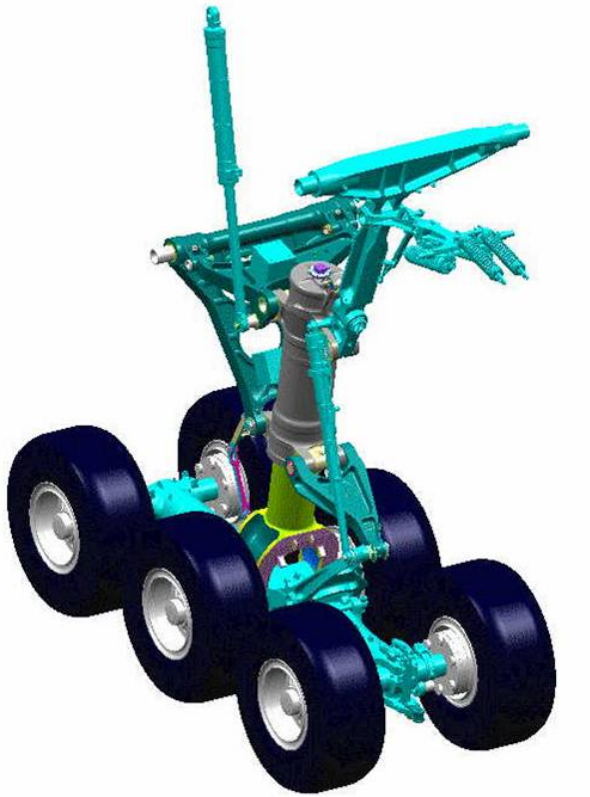
Testing Status

- 5” piston testing complete.
- The scope of the 10” piston tests is being re-evaluated.
- Testing on A380 components has surpassed the piston bend tests and the original test scope would only duplicate what we have already learned.

Additional Activities

Additional Activities

Goodrich is using HVOF on landing gear.



A380 Piston

Additional Activities

- The Airbus A380 design is the first Goodrich Landing Gear with HVOF coating as a hard chrome replacement.
- The A380 has achieved air worthiness certification.
- HVOF has performed very well.

Additional Activities

- Goodrich is working with Gulfstream introducing HVOF as a replacement for hard chrome on sustaining programs.

Additional Activities

Supporting Manufacturing

- Goodrich is continuing to qualify additional HVOF suppliers.
- Potential suppliers are evaluated for not only spraying capability but pre- and post spraying operations such as grinding, inspections, painting, etc. “one stop shopping”
- Sermatech International is installing a “shop within a shop” at the Goodrich Oakville facility to spray and grind HVOF.

Questions?