Progress on S53 for Rotary Gear Actuators
ESTCP Project WP-0619

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**Progress on S53 for Rotary Gear Actuators**

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Team

- Ogden ALC, Ryan Josephson (PI)
- QuesTek Innovations LLC (steel design)
- General Atomics (testing)
- Lockheed-Martin (F-35 prime)
- Moog (WFAS RGA manufacturer)
- Curtiss-Wright (LEFAS RGA manufacturer)
- BAE Systems (galvanic testing)
- Rowan Technology Group (coordination, cost analysis)
What is an RGA?

Geared system to rotate one set of tabs relative to another

Used on F-18 to operate wing fold

www.zakgear.com/
RGAs on F-35 Lightning II

RGAs used for

- Wing fold actuator system (WFAS)
  - Carrier variant
- Leading edge flap actuator system (LEFAS)
  - All variants
Design materials

- MP35N Ni alloy rods
- HP-9-4-30 or 4340 high strength steel gears (Cd plated)
- 17-4PH stainless bushings
- Ti wing spar
- Bad galvanic couples

Bushings: 17-4PH in Ti spar
MP35N in gear
Galvanic corrosion of current system

Cracks

Missing Lugs
Extent of the problem

- This is a problem with all F-18 lugs
  - Matter of severity
  - Cracks come from corrosion pits

- Want to avoid this problem on F-35

- S53, being a CRES alloy, will not have progressive corrosion
  - But could still have pitting corrosion leading to fatigue

- S53 also has much better $K_{1C}$ and $K_{1SCC}$ so cracks will not grow as fast
Because S53 designed for landing gear, not RGAs, program defined 1-year Risk Reduction

- Corrosion (galvanic, crevice) at BAES in UK to match previous F-35 LEFAS testing
Parallel F-35 Program Office test program at Curtiss-Wright

- C-W testing of growth on heat treating showed growth uniform and predictable
- Machining of test parts showed S53 is machinable in C-W shops
  - But must be sent out for heat treating as uses cryogenic steps
- C-W contracted to manufacture S53 LEFAS as demonstration and carry out mechanical testing of coupons
STREAMLINED CORROSION TESTING OF S53 FOR RGAs

Components
- Pin MP35N – refurbished from previous trials
- Titanium plate with 17-4PH bush – also refurbished from previous trials
- Gears made from HP9-4-30 or S53 with MP35N bushes
ASTM G85, SO$_2$ salt spray testing completed October 22, 2007

Plate - Titanium AMS 4911-A
Bushing 17-4PH

Pin - MP35N
Ni-based superalloy
Bushing MP35N
Disc - HP9-4-30 or A 100
End of test (14 days, 336 hr)

Cd plating does a good job of corrosion protection. But adhesion of non-Cr primer is poor (needs better surface prep, vendors need to develop experience).

Test #1, 2 HP9-4-30, Cd plated
Delamination of paint near bushing
No corrosion of HP9-4-30

Test #4, 5 S53, Cd plated
Delamination of paint near bushing
No corrosion of S53
Final Test Results – after 14 days

Test #3  S53, Boegel AC131 (Not Cd plated)

No delamination of paint – very good paint adhesion to AC131
Slight corrosion of S53, on exposed edge between bushing and paint (edge exposed because of limits to masking accuracy)
No corrosion found between S53 and bushing

This is a very encouraging result
Final Test Results – after 14 days

S53, Boegel (no Cd plate) – bush removed - Outer surface

(Paint removed using knife)
Conclusion on galvanic/crevice G85 corrosion testing

- Non-Cr primed and painted S53 similar to Cd-plated HP9-4-30
  - If Cd is undamaged
  - S53 much better if Cd is imperfect or damaged
- WFAS and LEFAS made with S53 gears that are only Passivated, Non-Cr Primed and Painted should pass Navy-required F-35 corrosion testing with performance seen in this test program
Next step – Materials validation

Corrosion
- Galvanic/crevice corrosion
  - Current baseline
  - Current baseline + AlumiPlate
  - S53 passivated, AC130, primed, painted
  - Concentrate on damage tolerance
    - In real world corrosion protection system damage is inevitable

Mechanical
- Paper study evaluation of alternative high strength CRES alloys
  - To be sure S53 makes most sense
- Gear durability, tooth fatigue, RCF
  - Core hardness probably sufficient
  - May need nitrided case
Qualification

- MMPDS listing and Class A allowables available shortly
- Full materials test results available shortly in Final Report of ESTCP S53 Landing Gear project
- Qualification of F-35 RGAs
  - Full LEFAS/WFAS units to be manufactured from S53
  - G85 SO₂ salt fog testing of full unit (requirement for all F-35 systems)
  - Full functional rig testing
  - If successful and cost-effective will enter program in LRIP
Technology Transfer

- RGA must be bushed to reduce galvanic attack
  - This increases the cost of the system
  - S53 is then becomes a cost reduction for new programs
  - Reduction of corrosion fatigue failures will be a cost reduction for legacy programs

- Tech transfer through Moog (WFAS) and Curtiss-Wright (LEFAS), who are manufacturers for all current systems on F-35, F-22 and F-18
  - If successful will initially enter production through F-35 LRIP
  - Would be drop-in replacement for F-18 WFAS
    - Qualification required

- Initial implementation may be made through use of S53 for F-35 jack, which uses the same type of RGA
  - And is not, of course, flight-critical!
  - But weaker cost driver