An Experimental Study of Fretting of Gear Teeth

Timothy L. Krantz
Army Research Laboratory
Cleveland, Ohio
Timothy.L.Krantz@grc.nasa.gov

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Experiments were conducted to study fretting of gears. The gears were made from case-carburized AISI 9310 alloy to match the material of a flight actuator gearbox of interest. The objective of the testing was to produce damage representative of that observed on flight hardware. The following correlations and observations were noted.

- The amplitude of dithering motion very strongly influenced the type and magnitude of damage.
- Sliding amounts on the order of 30% of the width of the line contact were judged to most readily produce fretting damage.
- There was observed an incubation period on the order of tens-of-thousands of cycles, and the incubation period was influenced by surface roughness, torque, and the motion extent.
- Fretting damage could be produced for any of the torques tested, and the severity of damage increased slightly with torque.
- Gear teeth having surface roughness of 0.7-0.8 micrometer were somewhat more resistant to fretting than were smoother surfaces.

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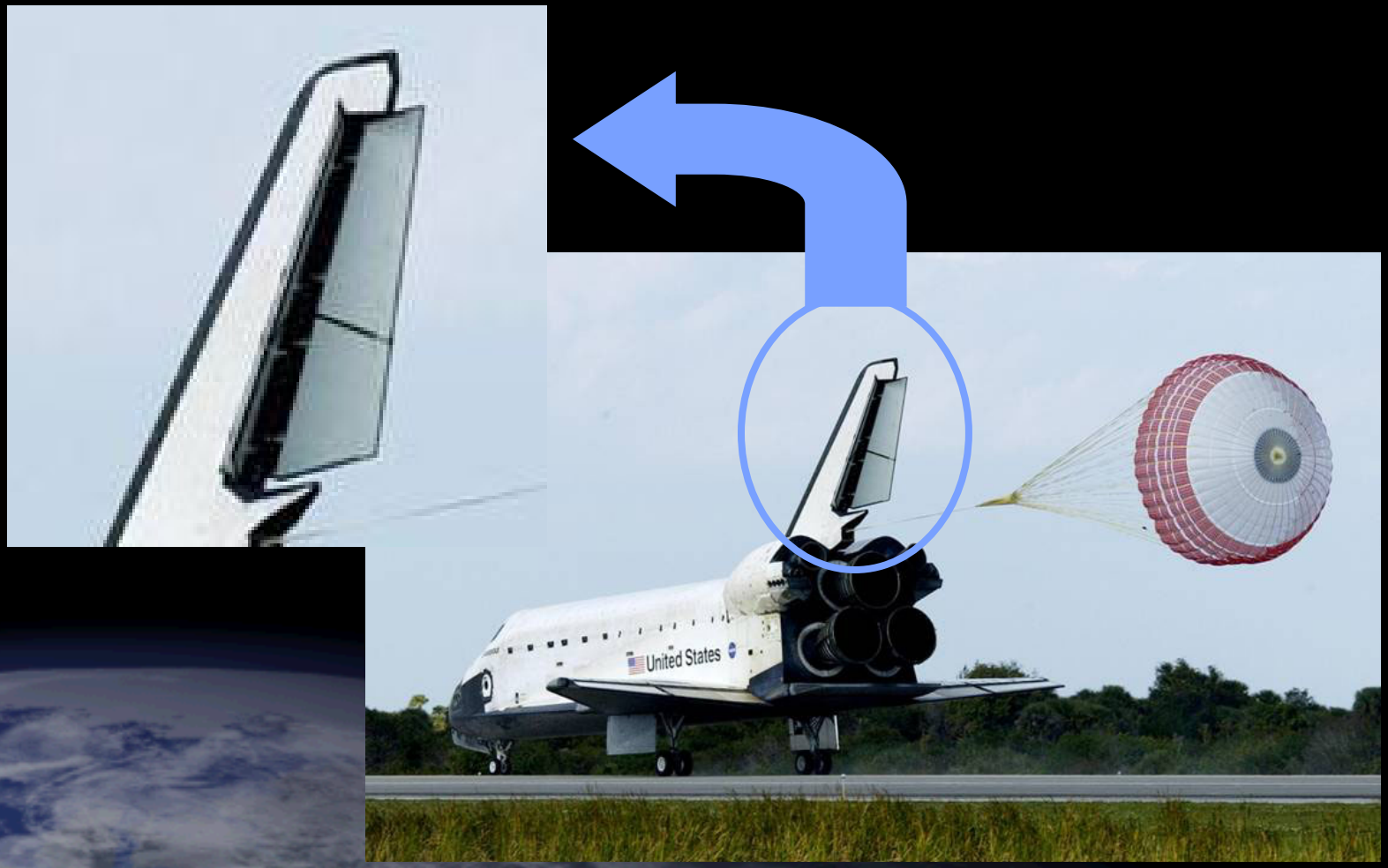
STLE 2008 Annual Meeting

Timothy Krantz, Ph.D.
Army Research Laboratory
Vehicle Technology Directorate
Cleveland, Ohio

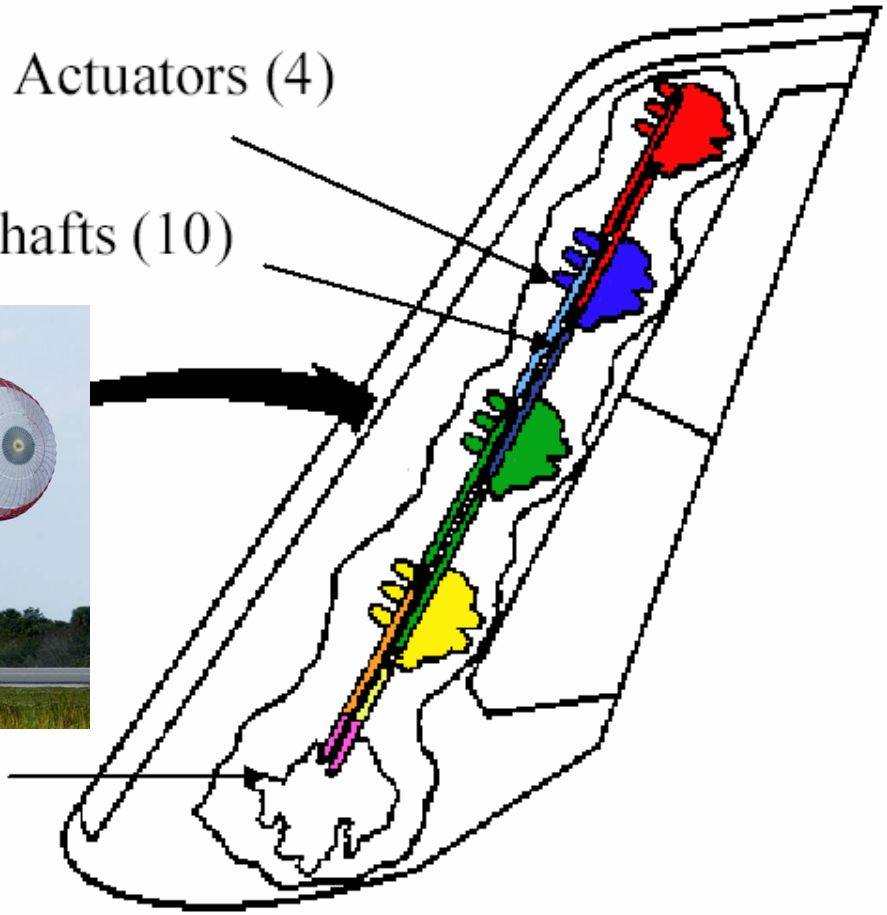
Outline

- Application (Space Shuttle Orbiter)
- Motivations
- Experimental setup
- Examples of fretting damage
- Summary

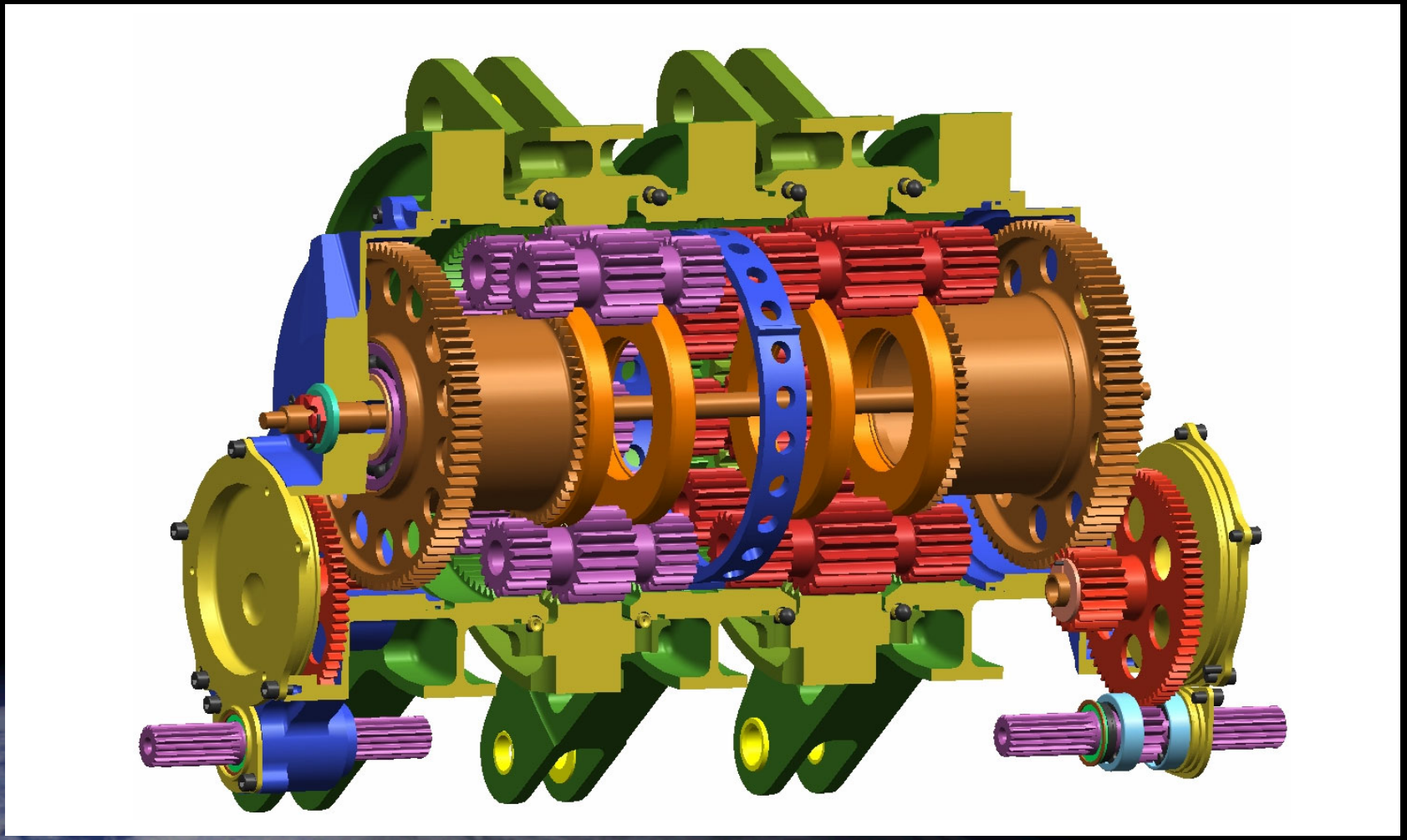
Orbiter With Speed Brake Deployed



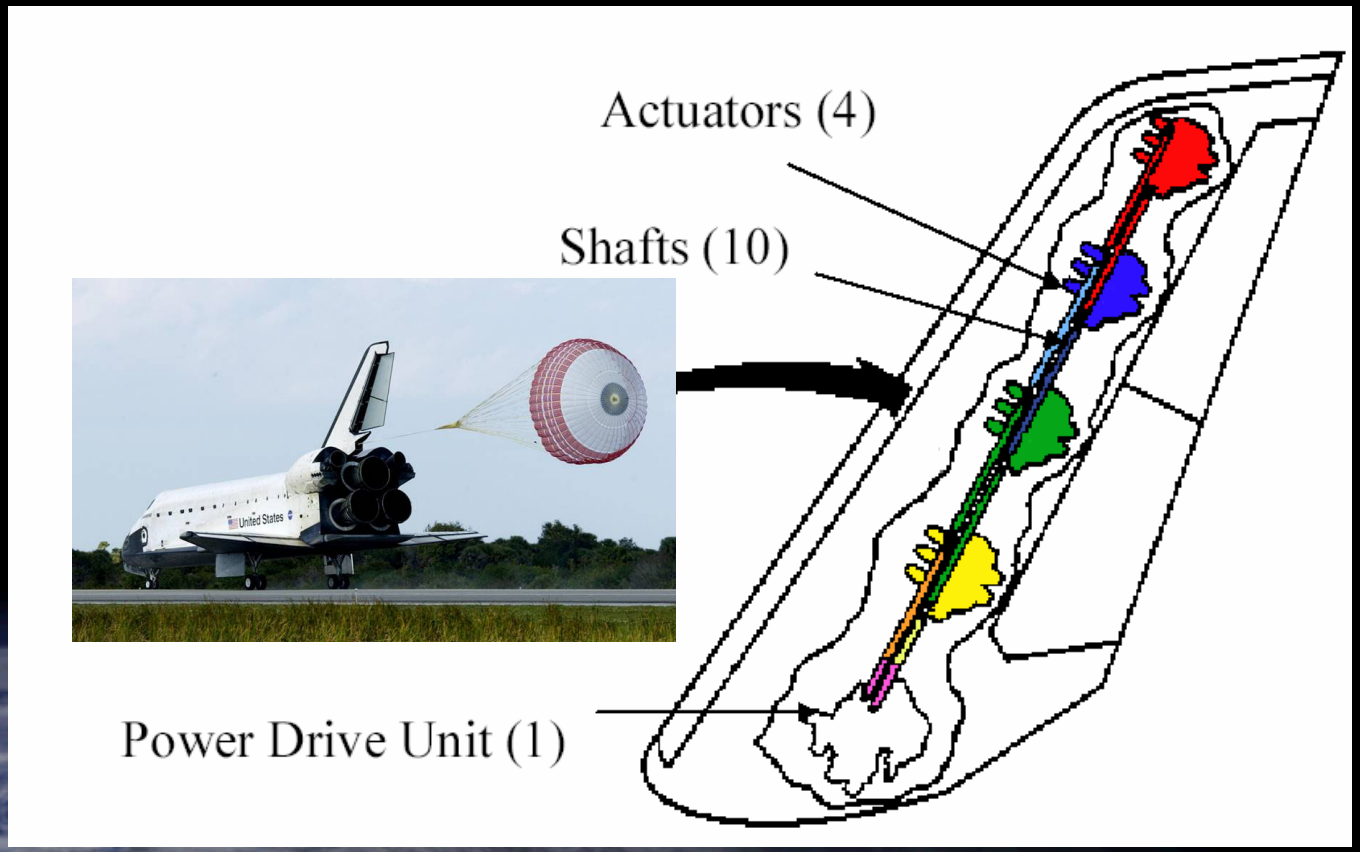
Actuators for Orbiter Rudder Speed Brake



Rudder Speed Brake Actuator - Cutaway View

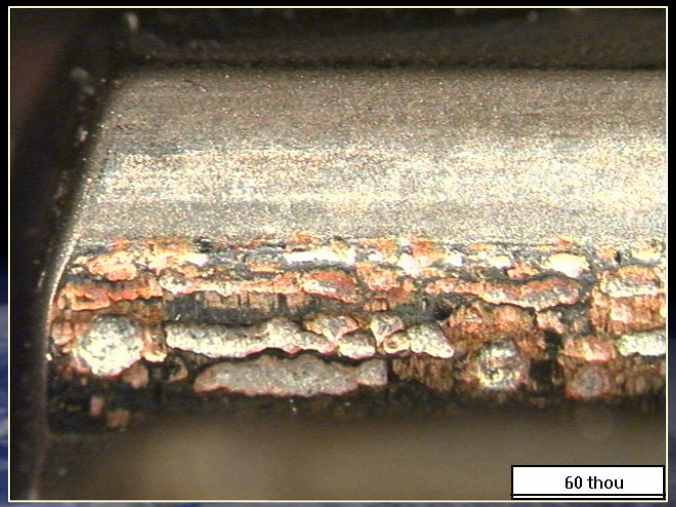


Rigging of Rudder Panels Requires Loading One Actuator Against Another

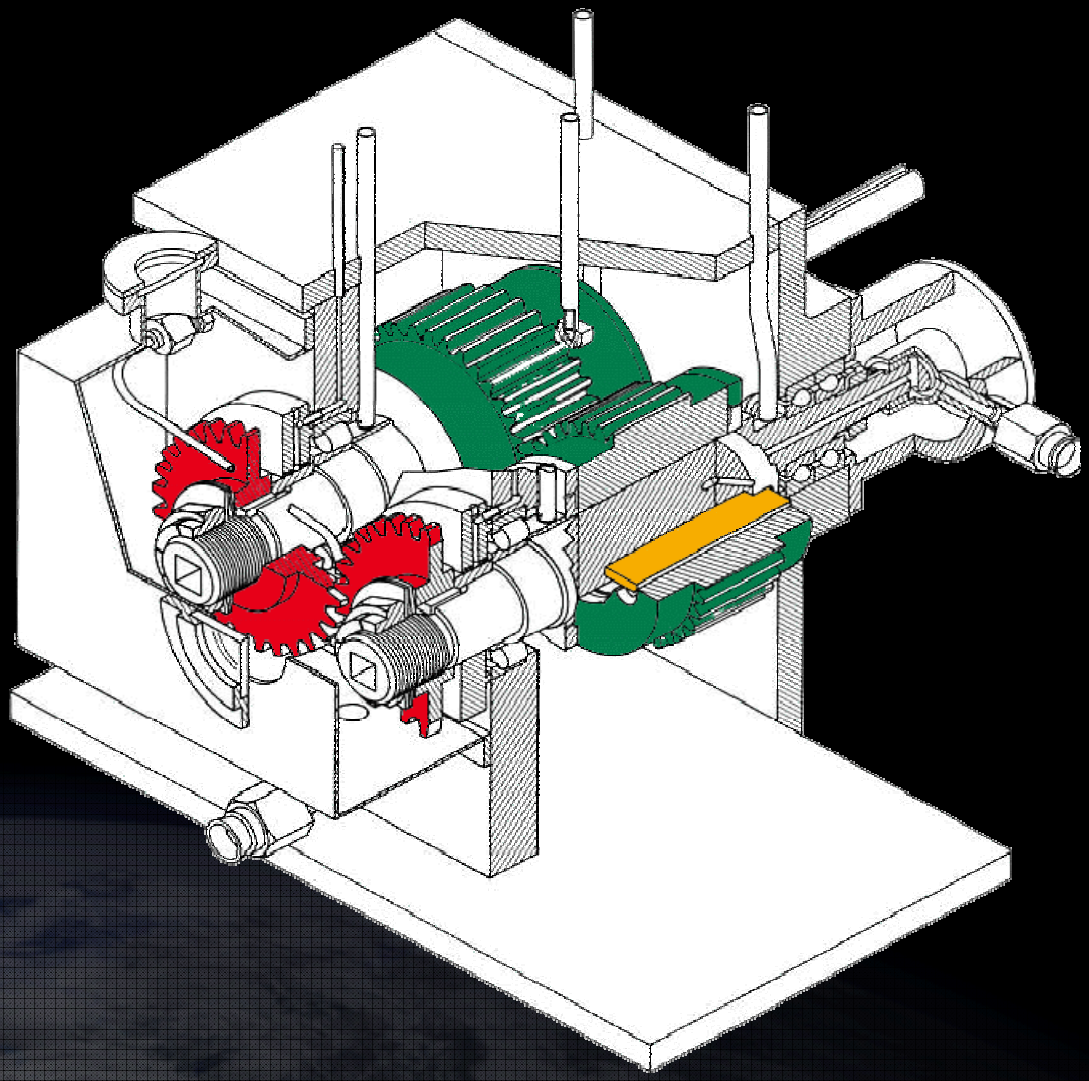


Motivations

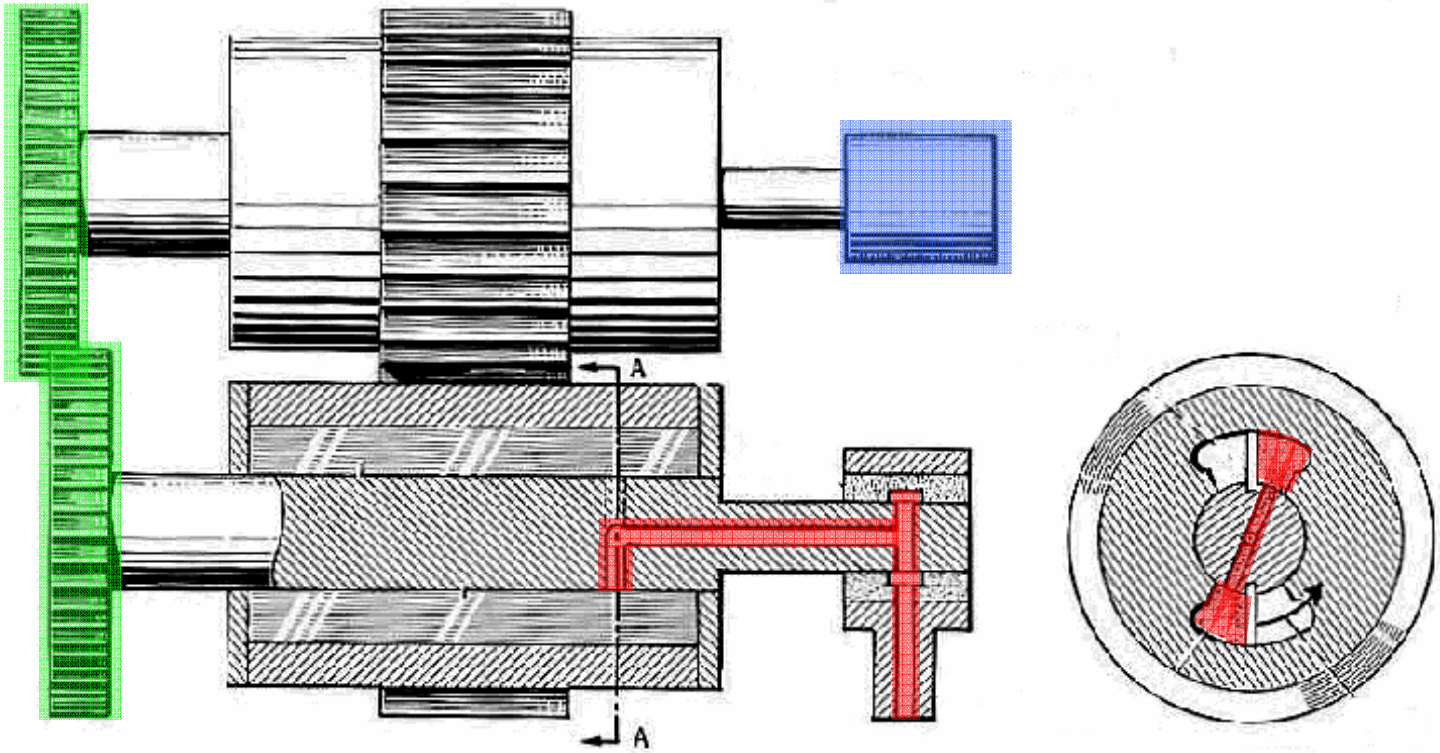
- Space shuttle orbiter flight control surfaces are positioned by geared mechanisms
- Inspections had revealed gear teeth with damage
- Laboratory testing was needed to understand the damage creation and propagation



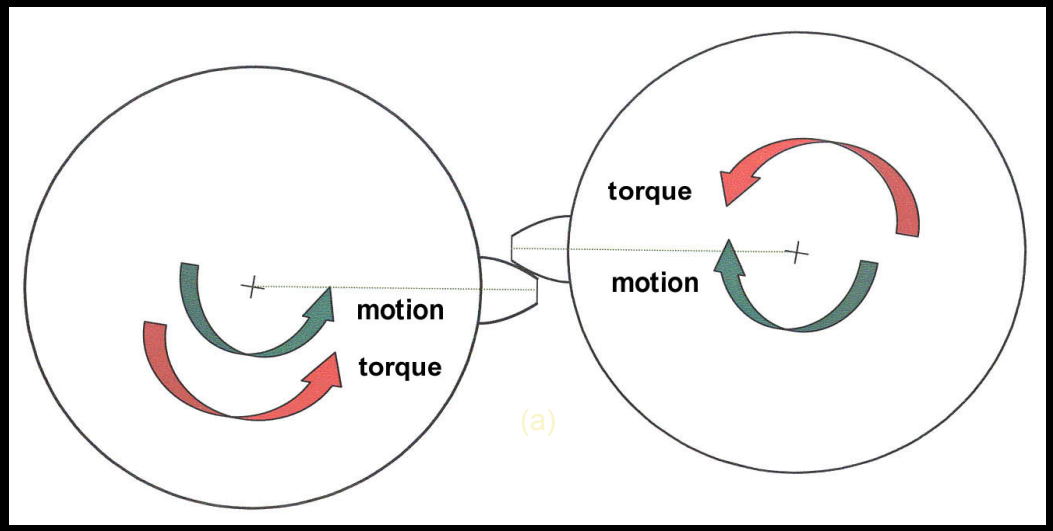
4-Square Test Rig

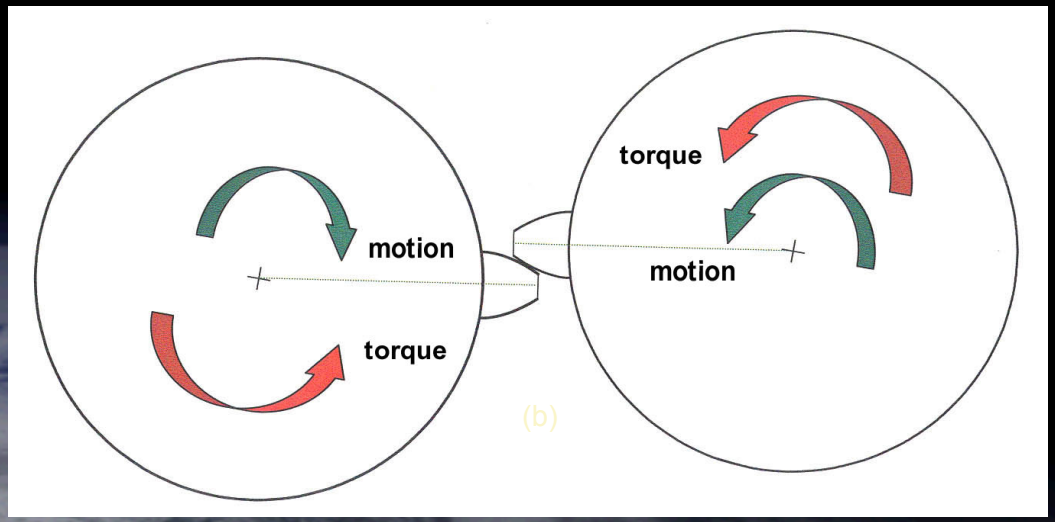


4-Square Test Rig



Dithering Motions

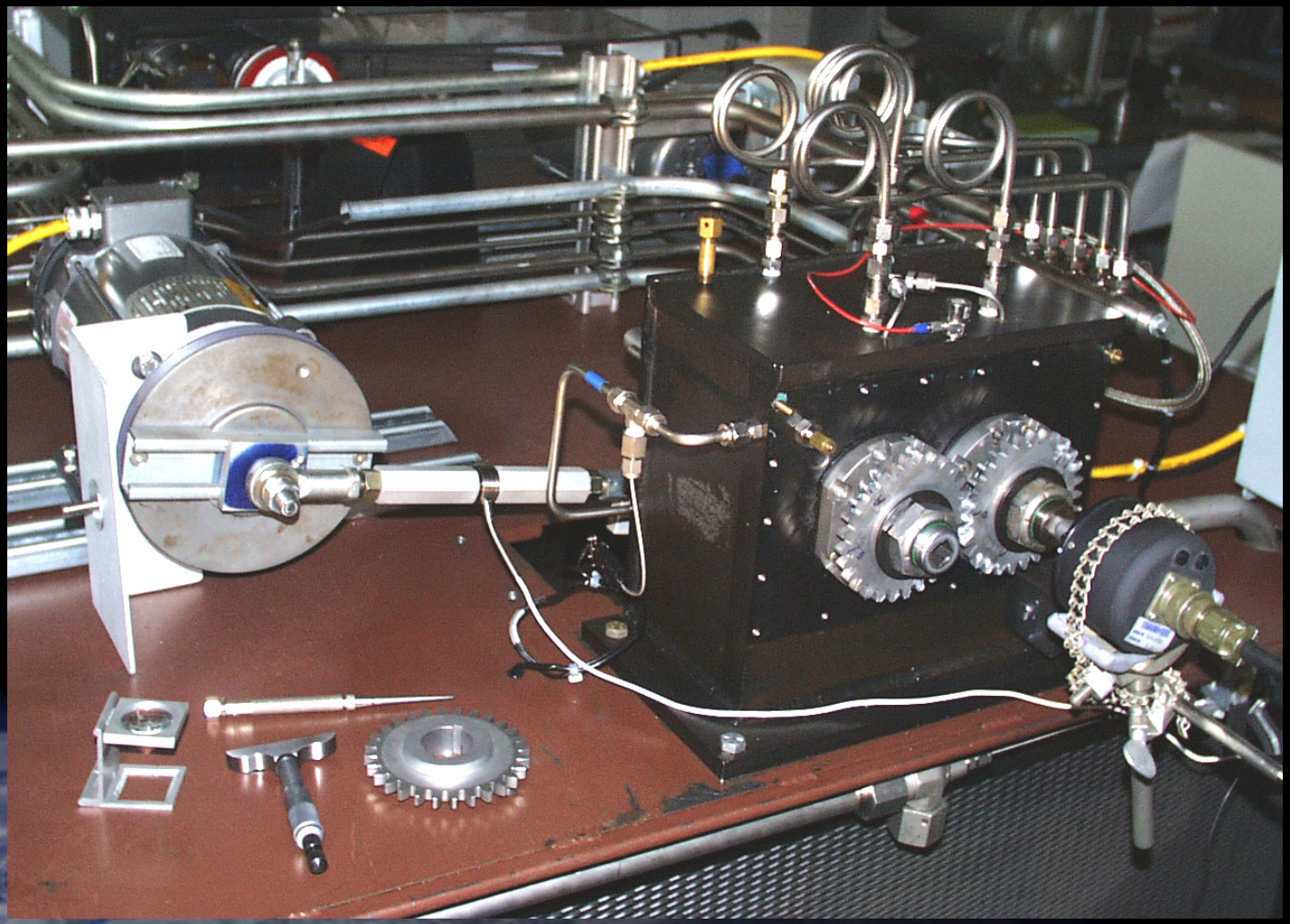




Test Gears and Grease

- Case-carburized and ground AISI 9310
- AGMA class 11
- 8 pitch (3.2 mm module)
- 6.4 mm face width
- Some gears has lead crowning, some did not
- Three levels of surface roughness (0.8, 0.4, and 0.2 μm R.M.S)
- Grade 2 perflourinated polyether grease

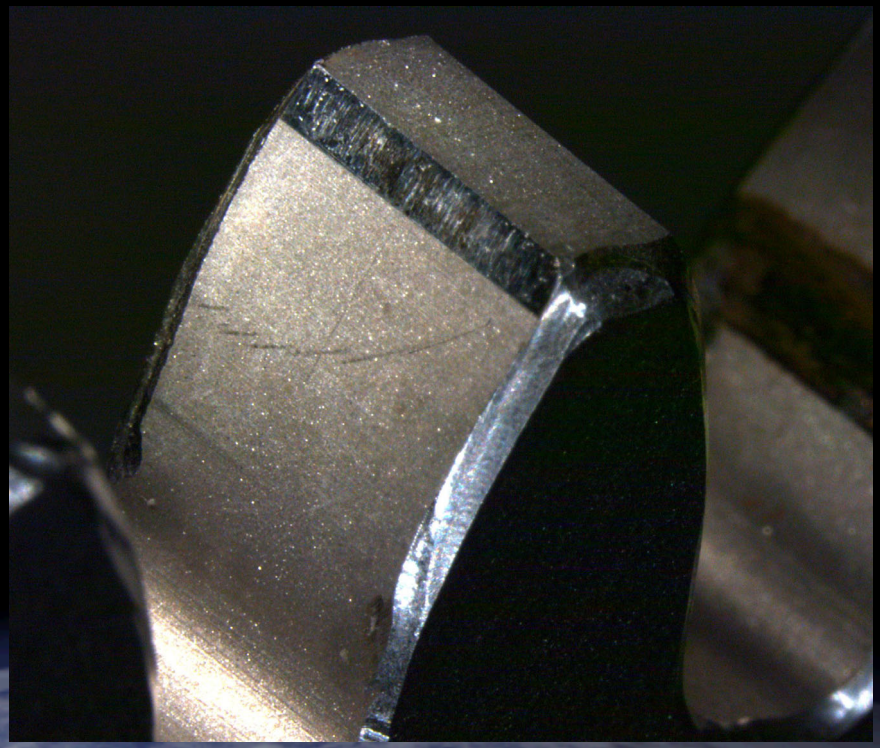
4-Square Test Rig

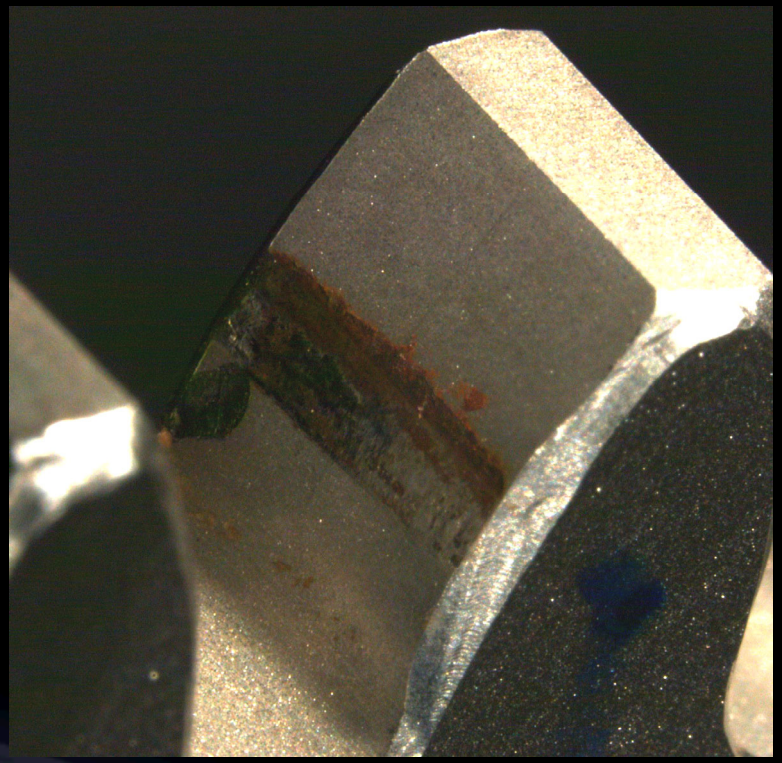


Testing Scope

- A series of 46 tests were completed
- Test variables included all of
  - Torque (load)
  - Range(s) of motion
  - Position of contact on the mating teeth
  - Surface roughness
  - With / without grease
- All testing was done in air (not vacuum)
- Test results were documented by digital photos and inspections via stylus profilometer

Typical Test Result – For case of line contact with load shared by two teeth





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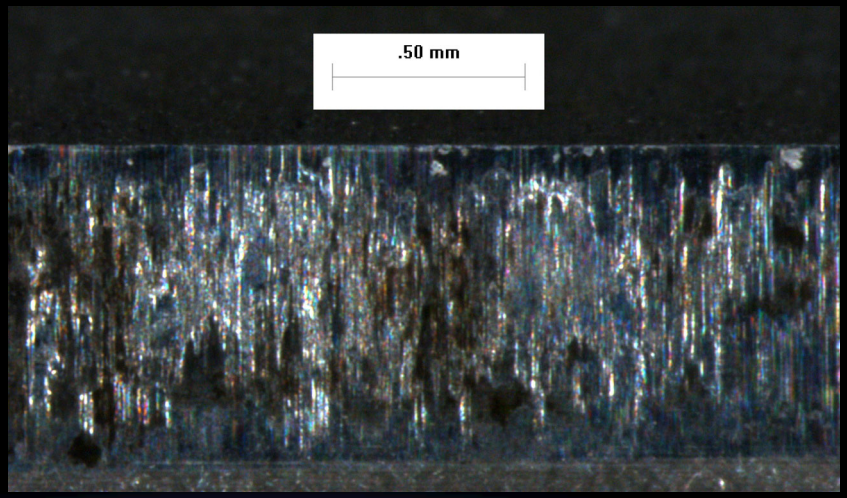
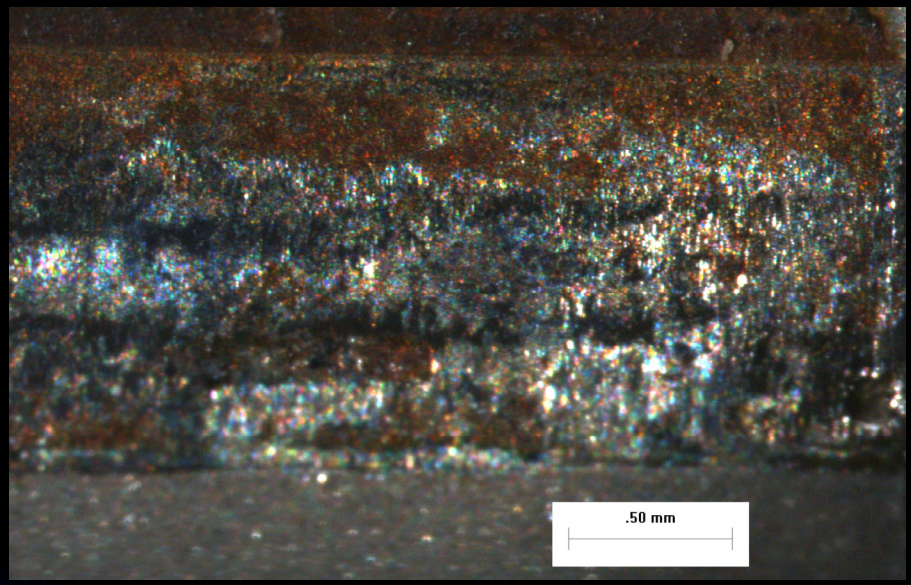
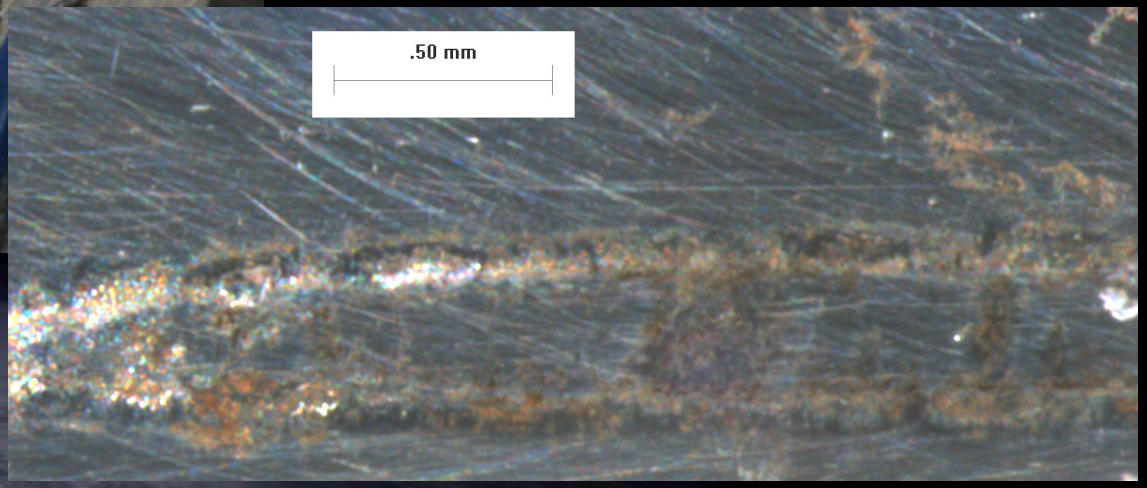
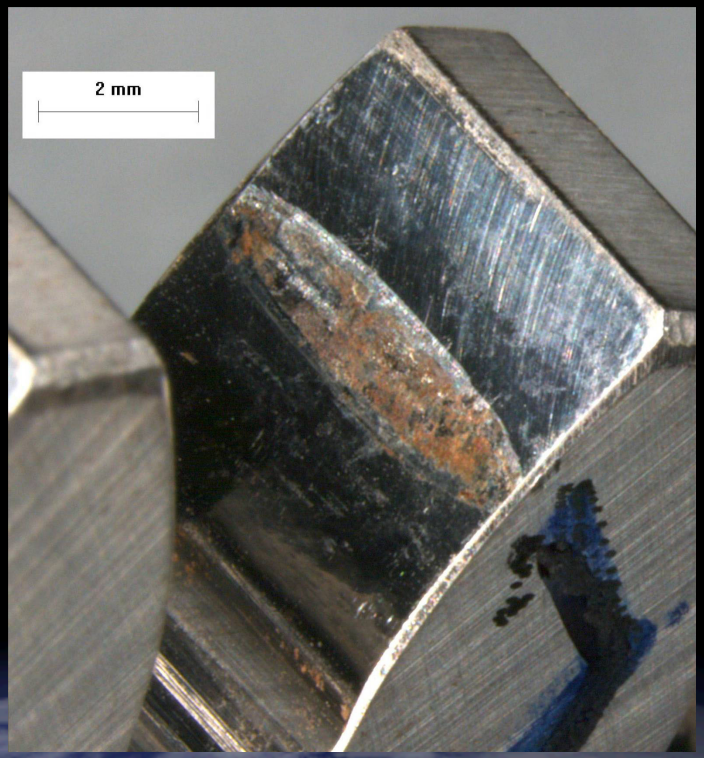


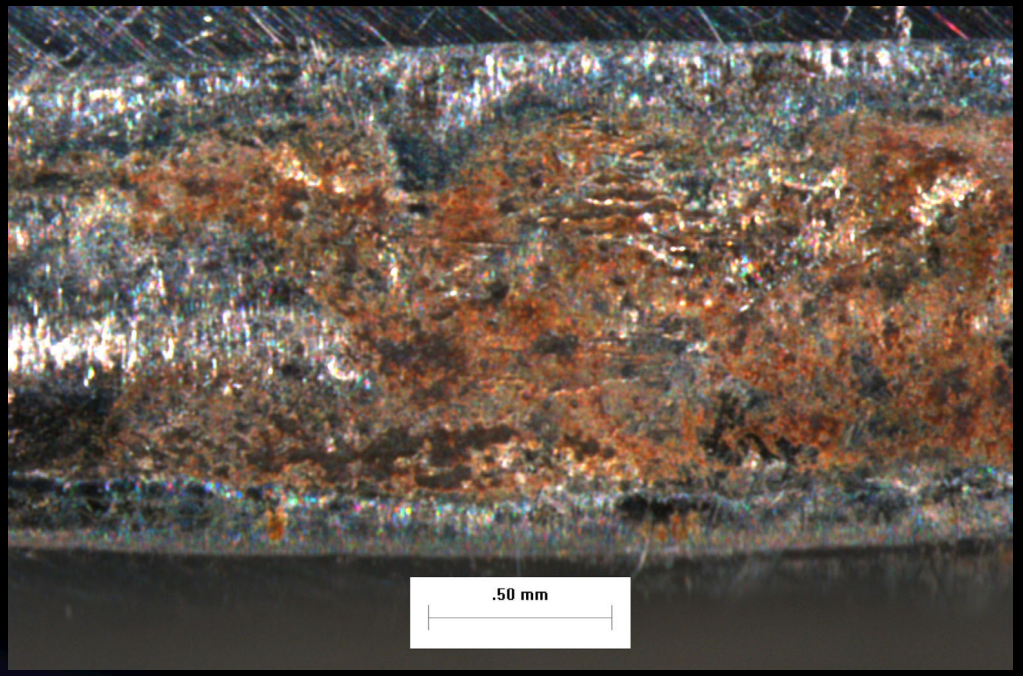


Test Result – For case of elliptical contact and small range of motion

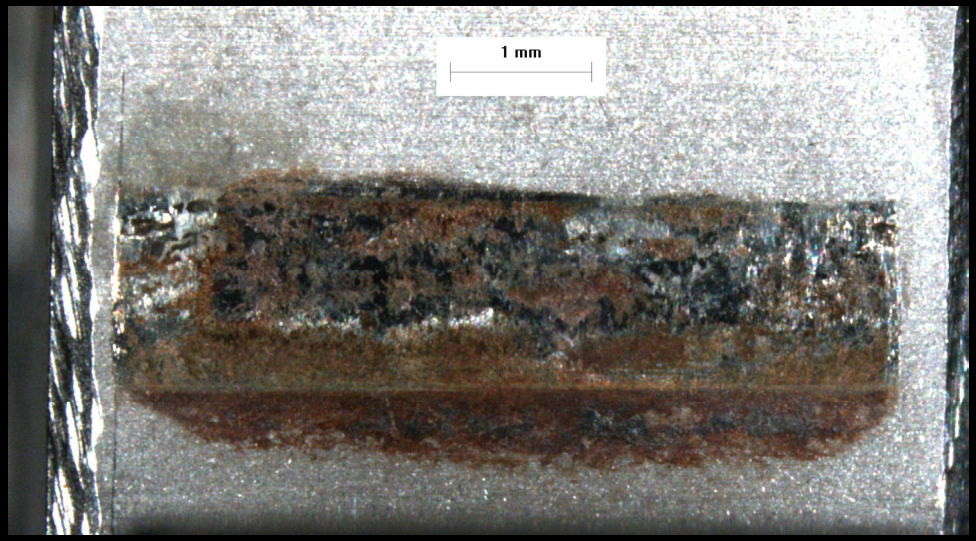


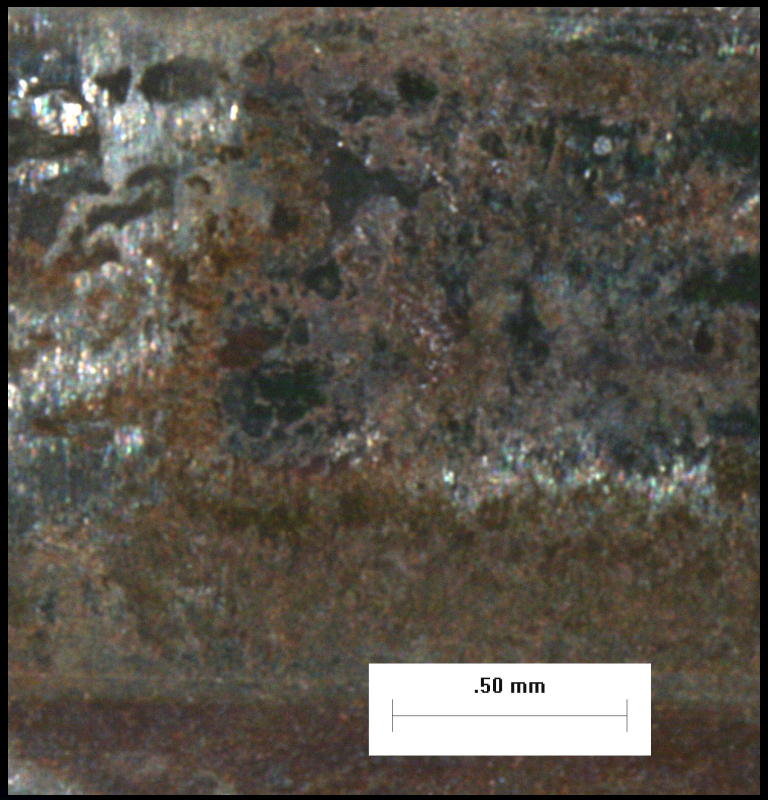
Test Result – For case of elliptical contact and larger range of motions



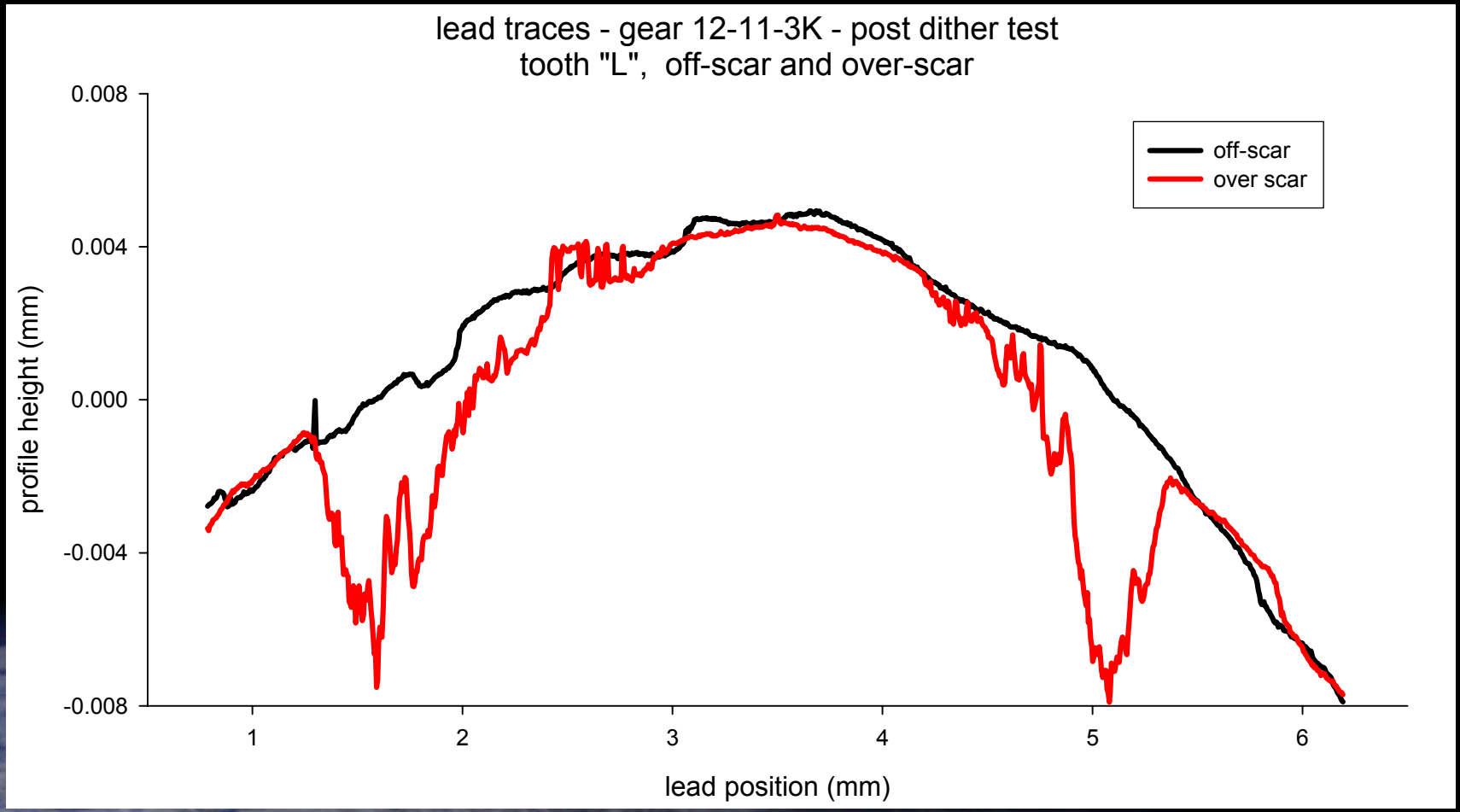


Test Result – Large and small motions

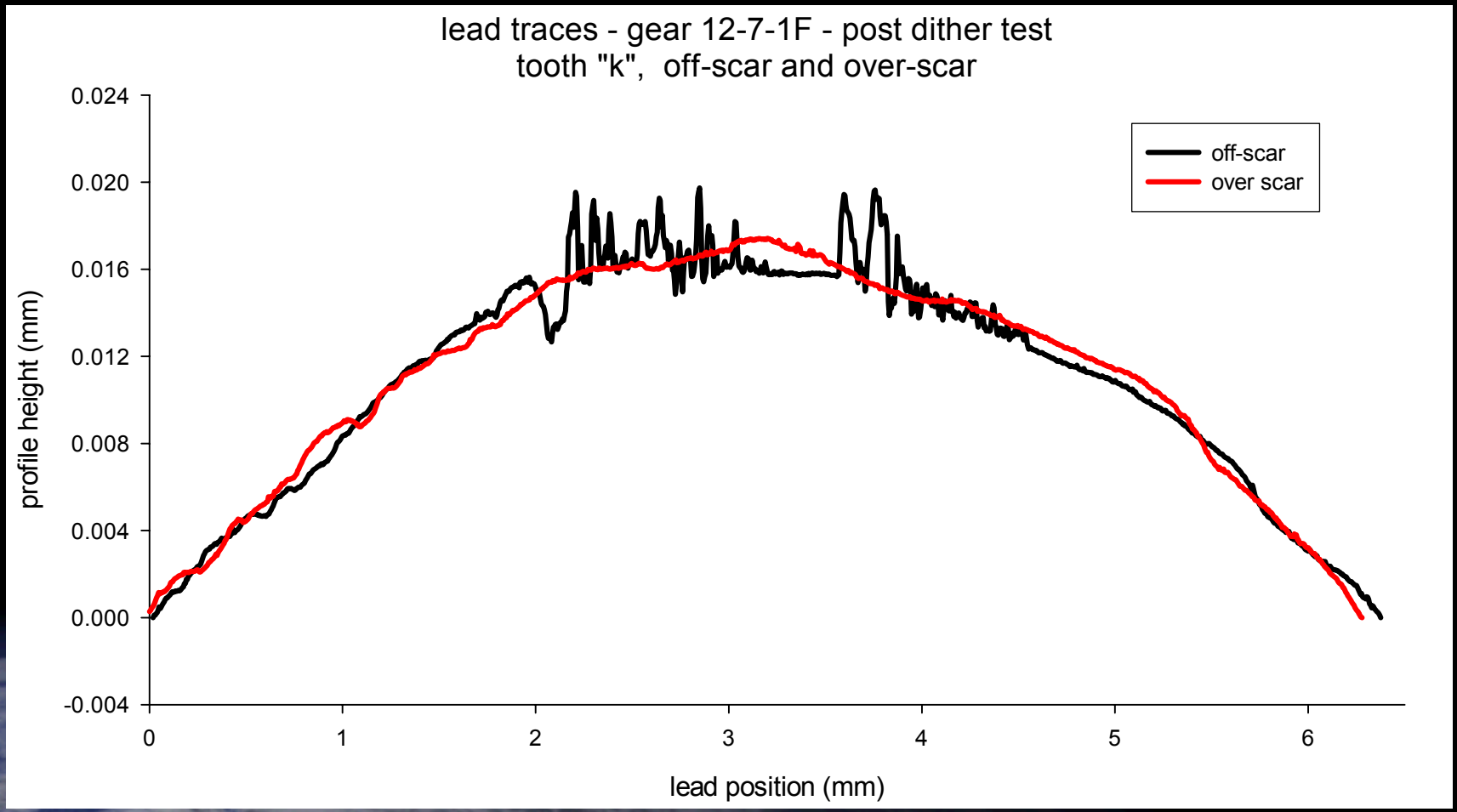




Profilometry Inspections



Profilometry Inspections



Pin on Disk Fretting Data for AISI 9310
R.C. Bill (ASLE, Vol. 21, 1977)

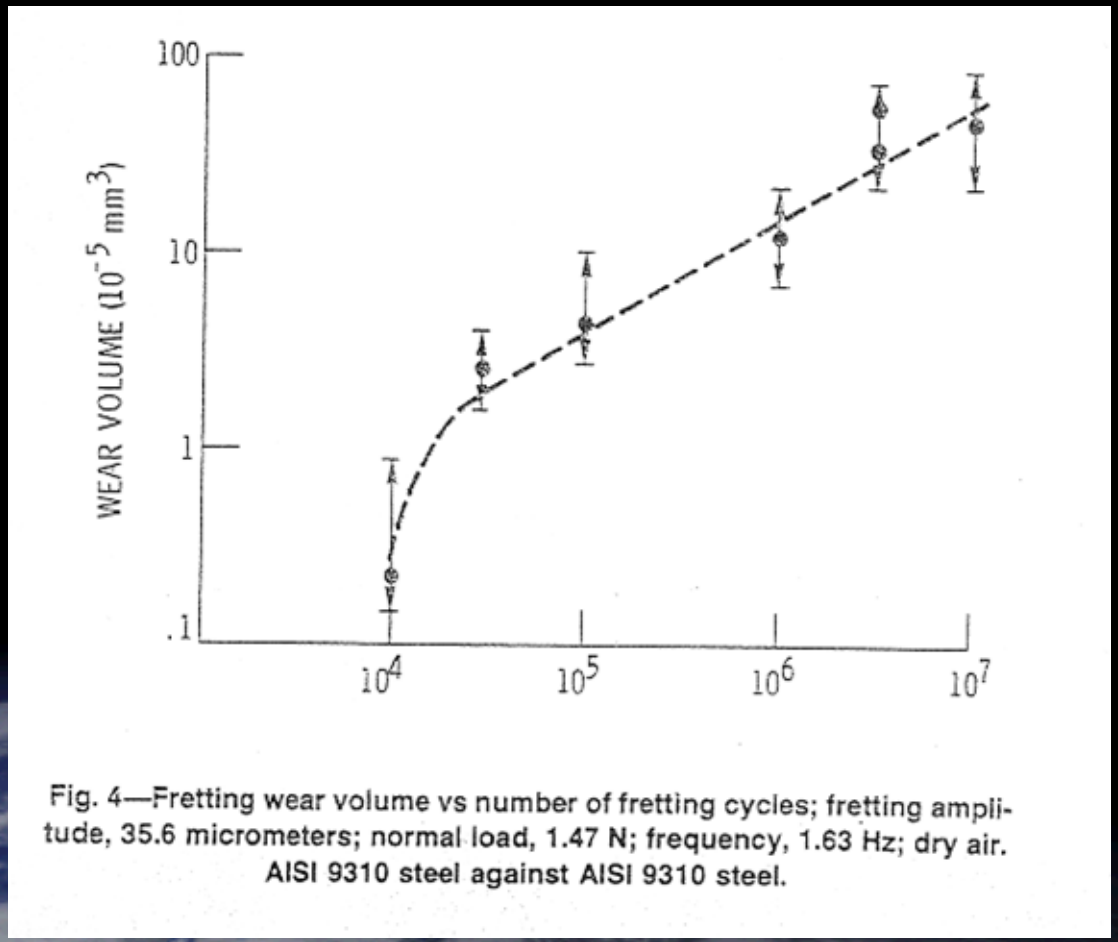


Fig. 4—Fretting wear volume vs number of fretting cycles; fretting amplitude, 35.6 micrometers; normal load, 1.47 N; frequency, 1.63 Hz; dry air. AISI 9310 steel against AISI 9310 steel.

- 66 KSI
- dry air
- 163 Hz
- .0014 inch motion

Summary

1. The amplitude of dithering motion most strongly influenced the type and magnitude of damage.
2. Fretting-type damage could be produced for any of the torques tested.
3. The severity of damage increased slightly with increasing torque.
4. Gear teeth having surface roughness in the range 28-32 microinch r.m.s. were somewhat more resistance to fretting as compared to smoother surfaces The rougher surfaces required more cycles and slightly larger amplitudes of motion to induce the same damage

Summary (Continued)

5. Damage progression was, for practical purposes, independent of the initial surface roughness.
6. There was an incubation period of tens-of-thousands of cycles for fretting to begin. The incubation period was influenced by all test variables.
7. Sliding amounts on the order of 30% of the width of the Hertzian contact width were judged to most readily produce fretting.
8. Tests that included a combination of large-amplitude and small-amplitude motion testing reliably produced damage that was visually consistent with flight hardware.