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Hybrid Gear Performance Under Loss-of-Lubrication Conditions

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Outline

- Background
- Hybrid gear design
- Experimental setup
- Results
- Conclusions
- Future work

Background

What is a hybrid composite gear?

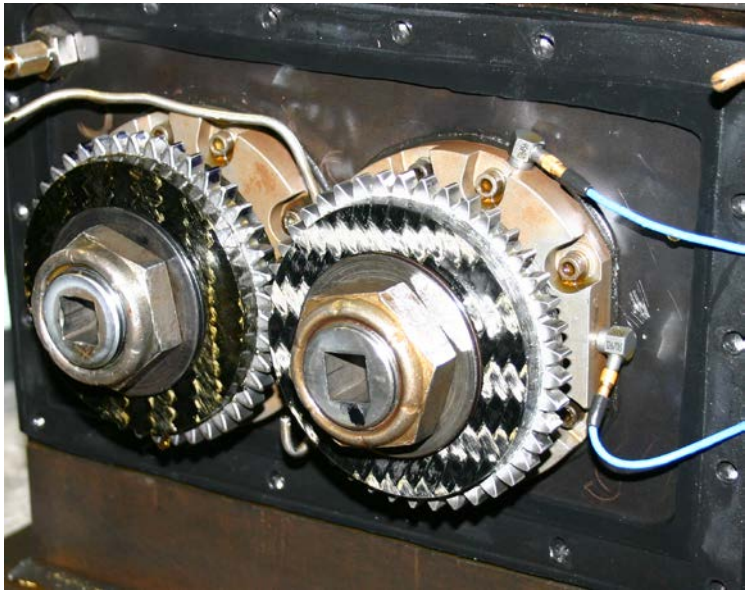
- Hybrid composite gear replaces the structural steel portion of a gear with a lightweight composite material

Why hybrid gears?

- Hybrid gears offer a potential to increase the power density in drive systems.
- Advanced vertical lift configurations are pushing for multi-speed capability, requiring additional driveline components

Past Efforts

Small-Scale



3.5 inch pitch diameter hybrid gears

- One million cycle endurance test
- Static torque test

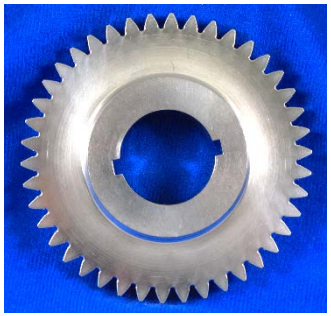
Large-Scale

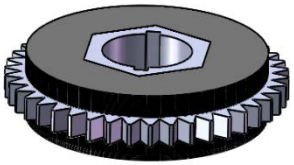
16.5 inch pitch diameter hybrid bull gear

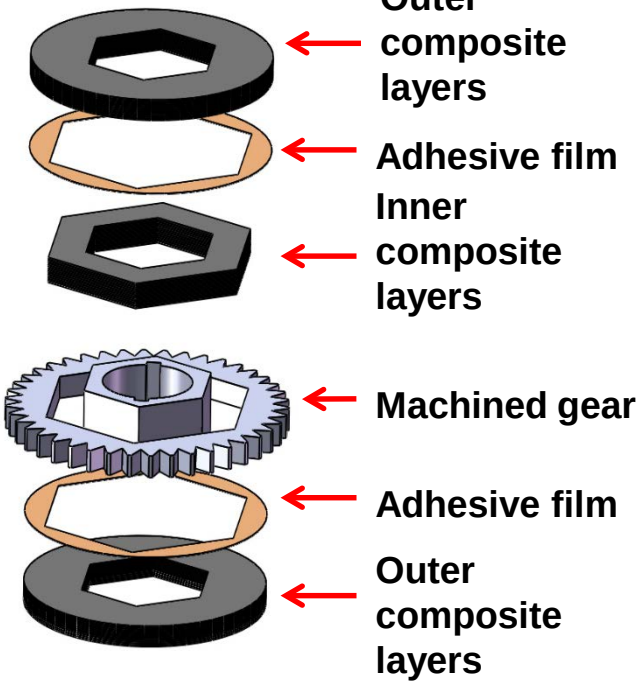
- One million cycle endurance test at 3300 hp
- Operational testing at 5000 hp
- Static torque test on the web

What about operation under adverse conditions?

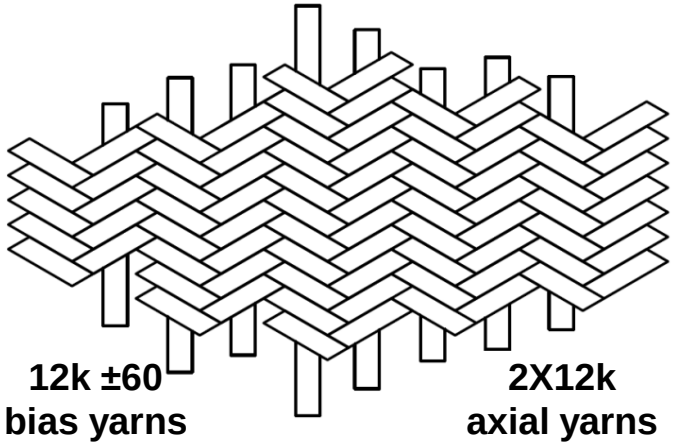
Hybrid Gear Design





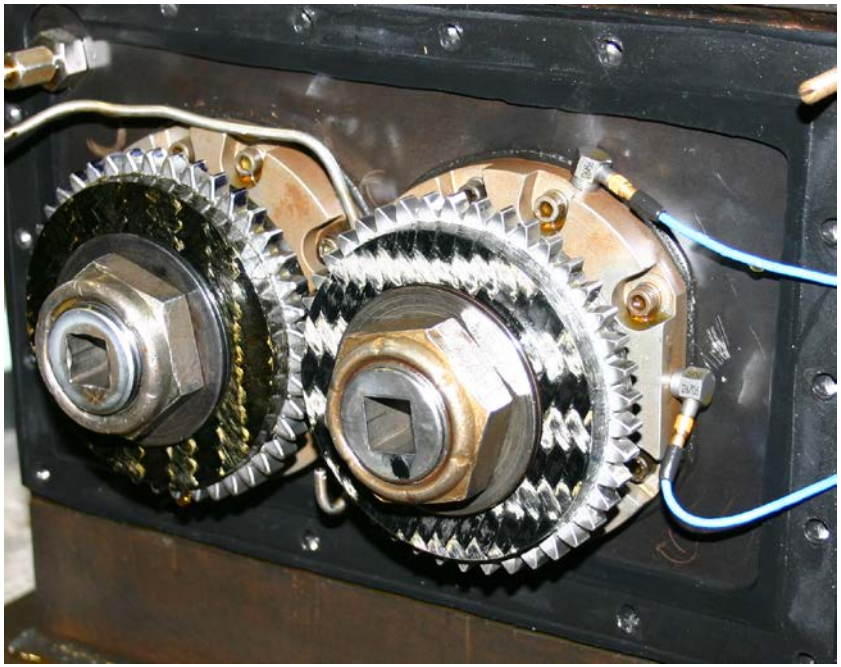


Triaxial Braid Architecture



- T700S-50C standard modulus fiber
- Prepreg / compression molding approach for flat web element
- ACG MTM45-1 resin with MTA241 film adhesive

History

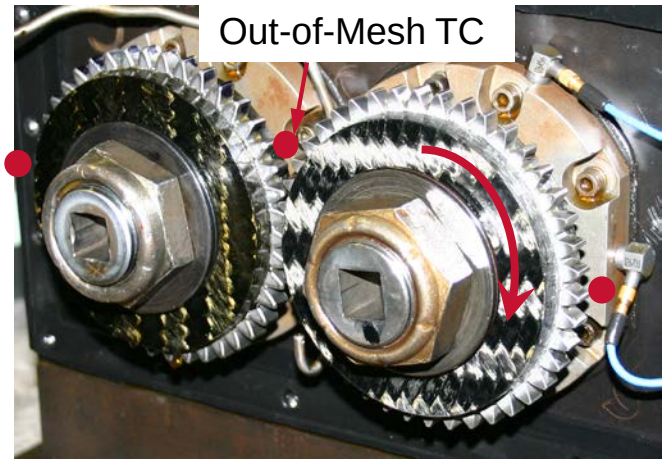


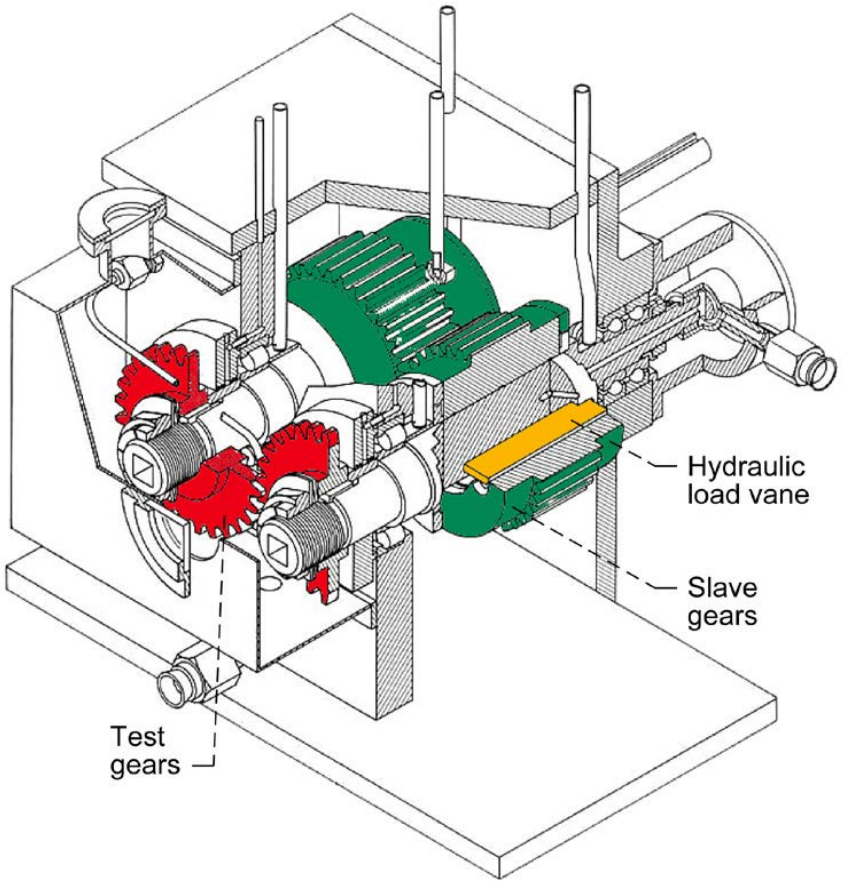
- Gears were reground to correct distortion caused by the curing process – Resulted in increased backlash
- Endurance test (10,000 RPM, 490 in-lb) completed to 10^9 cycles
- Two hybrid gears used, no damage detected after endurance test

Experimental Setup

Procedure

- Green Run at 10,000 RPM and 210 in-lb for at least 1 hour
- Increase torque to 520 in-lb
- At thermal equilibrium turn off oil supply pump and cap supply line
- Continue test until failure

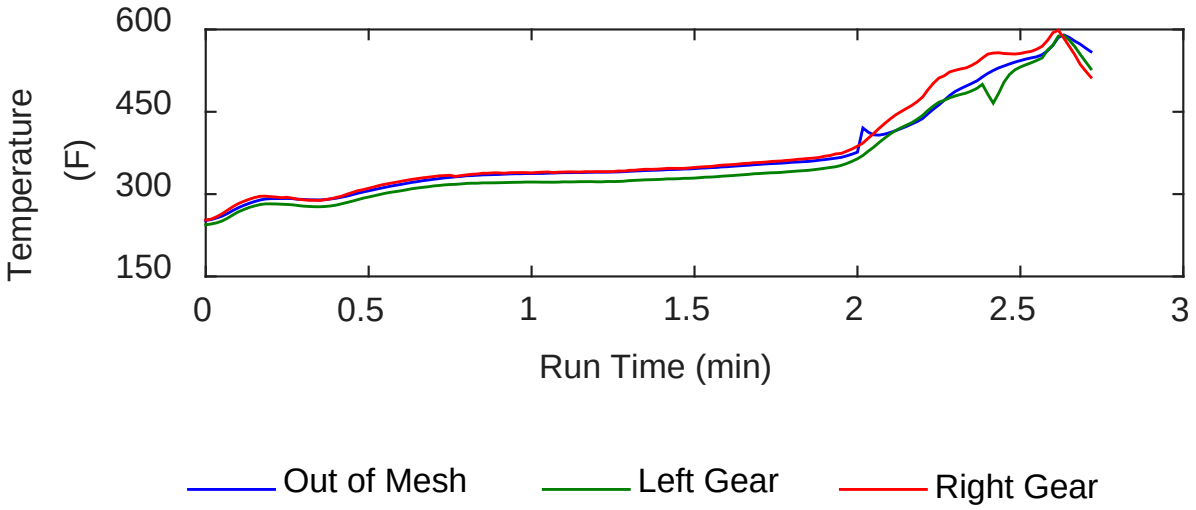


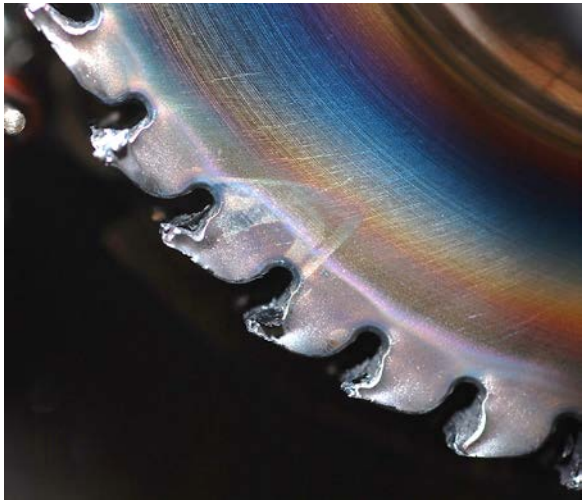


Contact Fatigue Test Rig at NASA Glenn Research Center

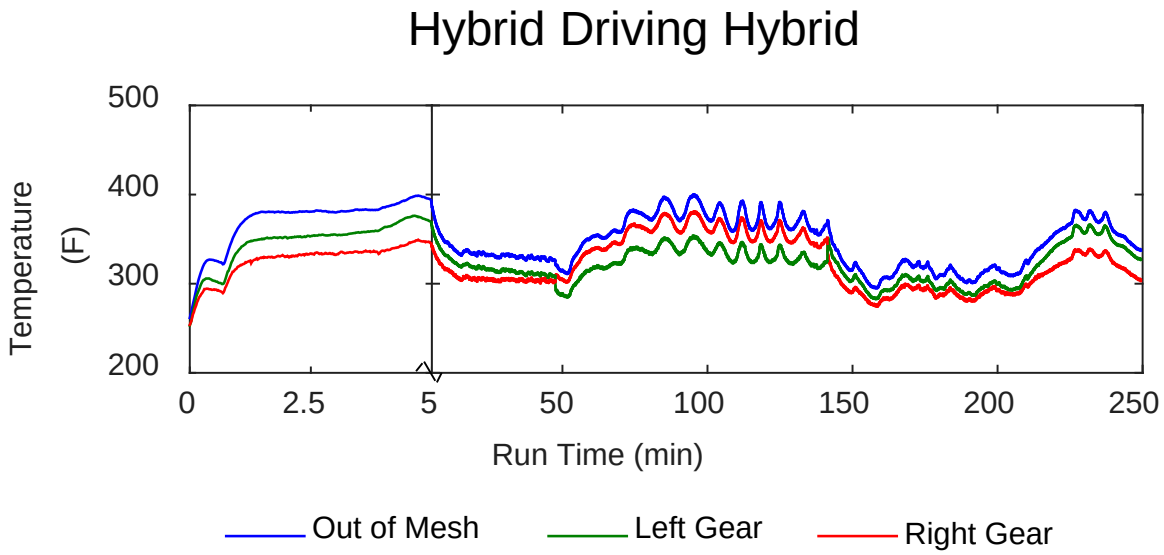
Results - Baseline

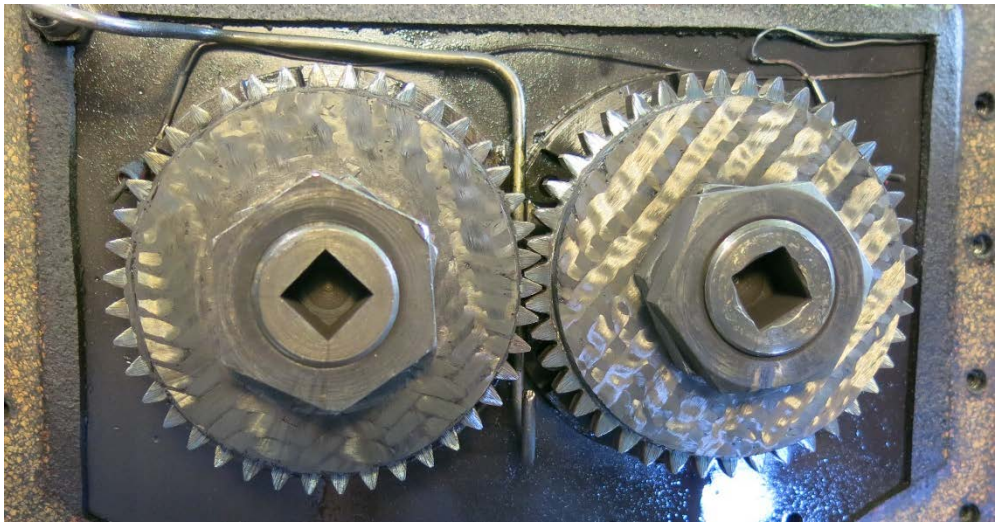
Steel Driving Steel (Unshrouded)





Results - Experiment 1

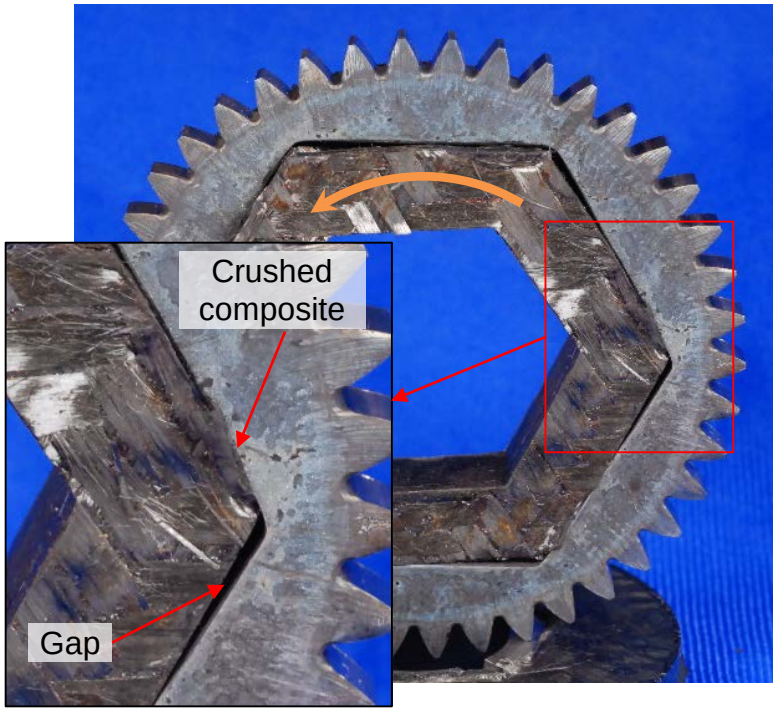




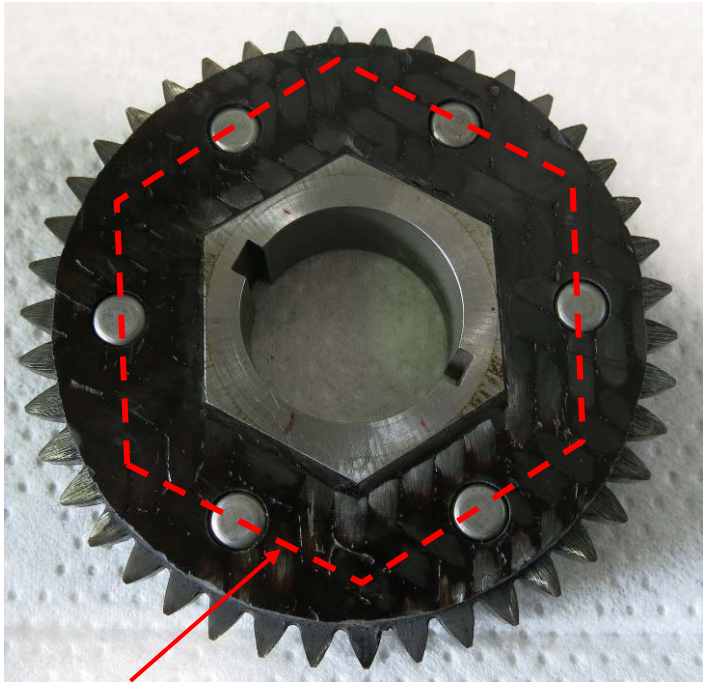
- After shutdown loss-of-torque was verified
- Visual inspection showed that the hub had rotated with respect to the teeth on the left gear

Results - Experiment 1

Disassembled left gear

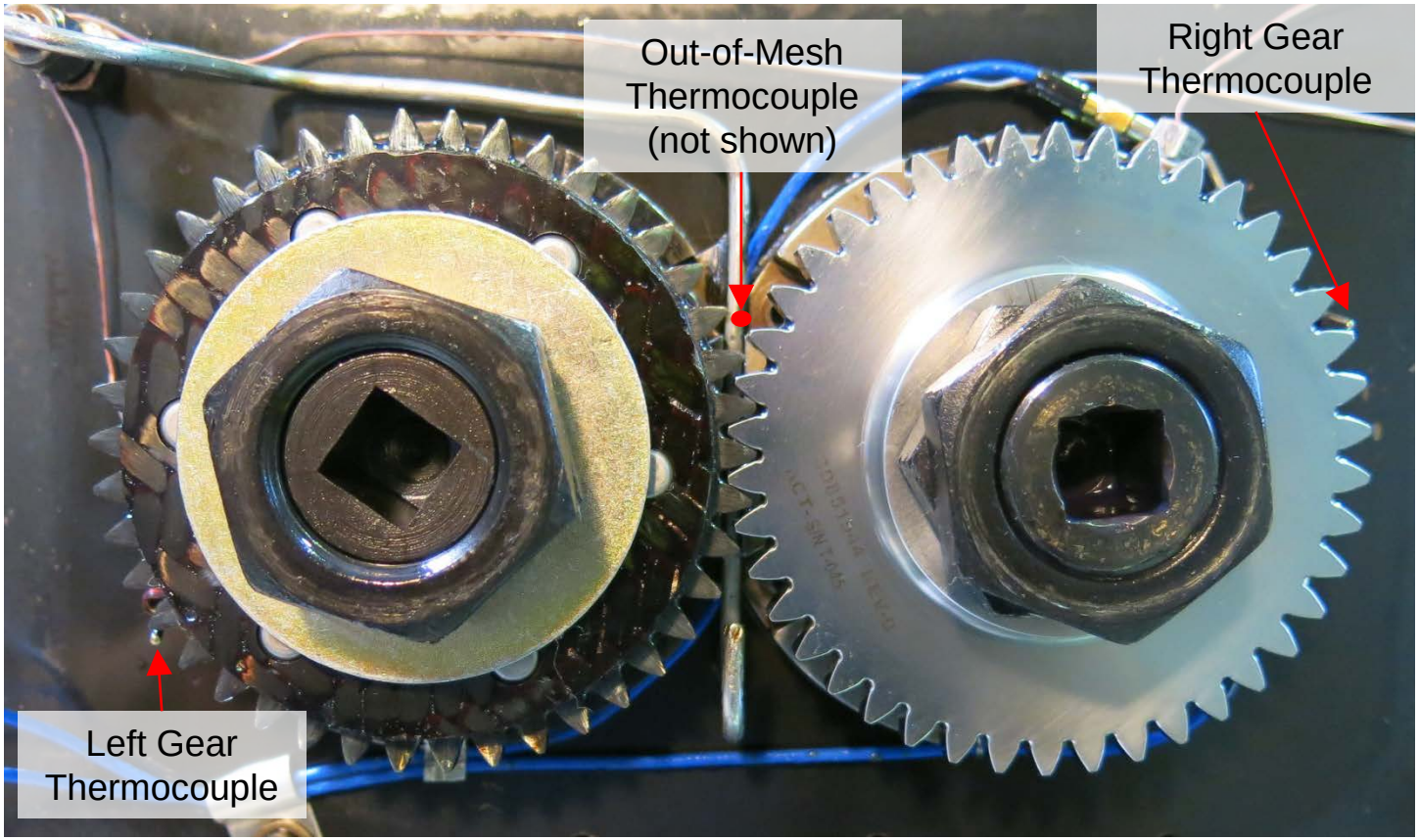


Modified right gear

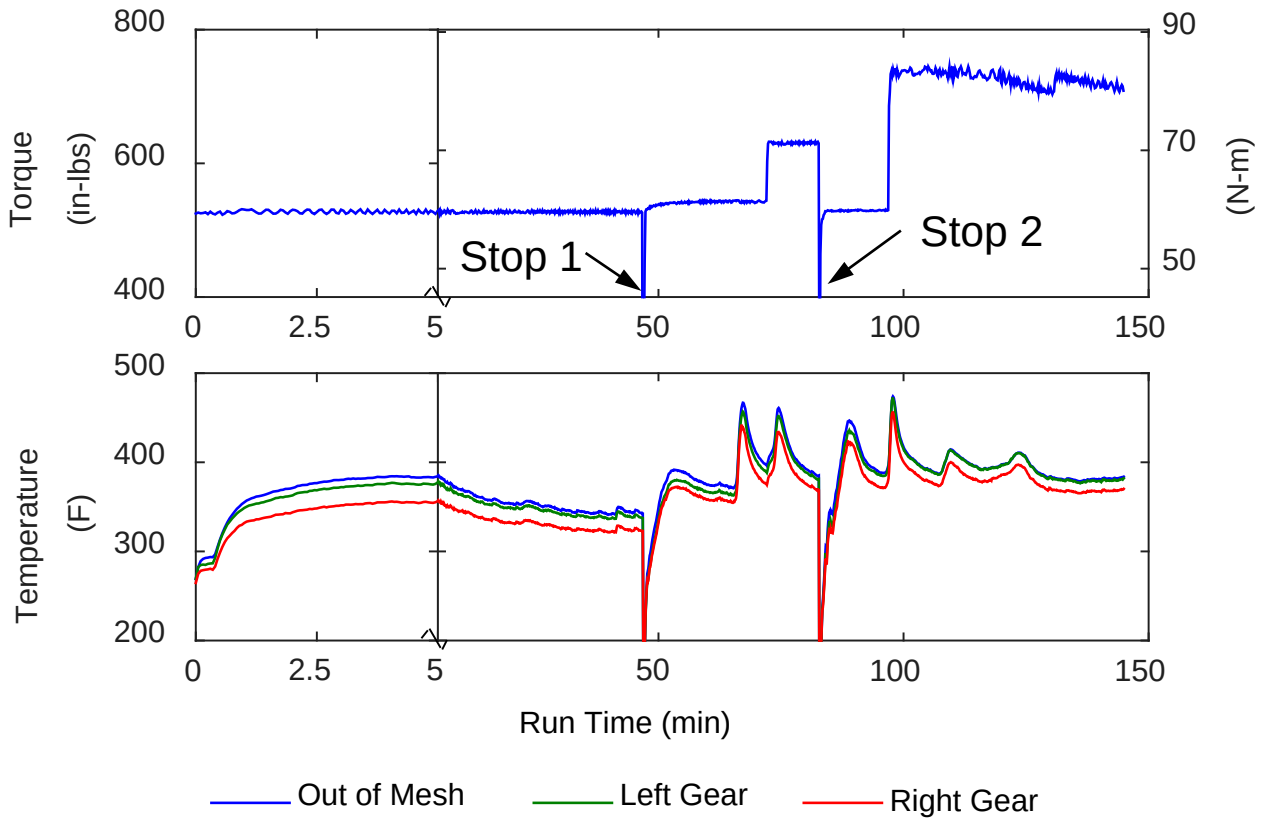


Approximate location of interlock pattern

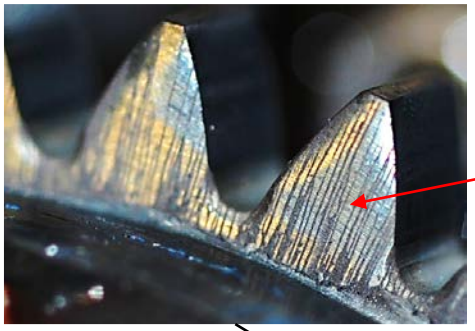
Experiment 2



Results - Experiment 2

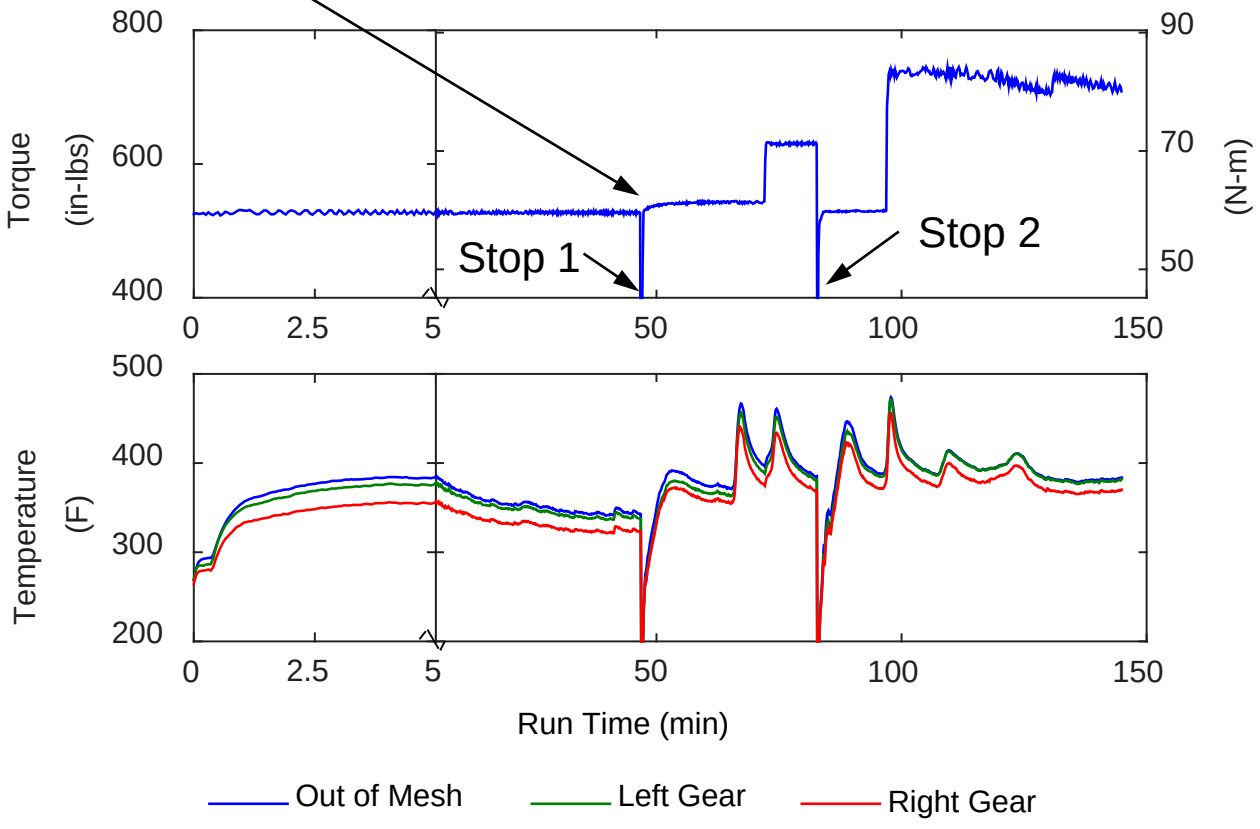


Results - Experiment 2

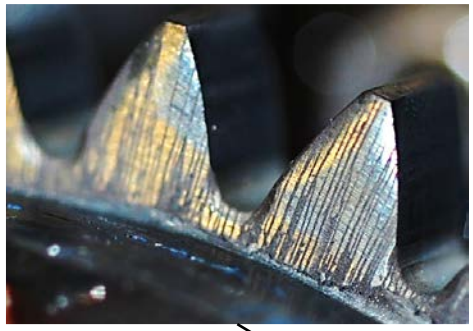


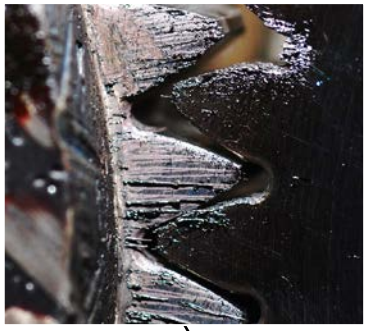
Stop 1

- Torque transfer verified
- Black lines documented on teeth
- Restarted experiment dry and reapplied load



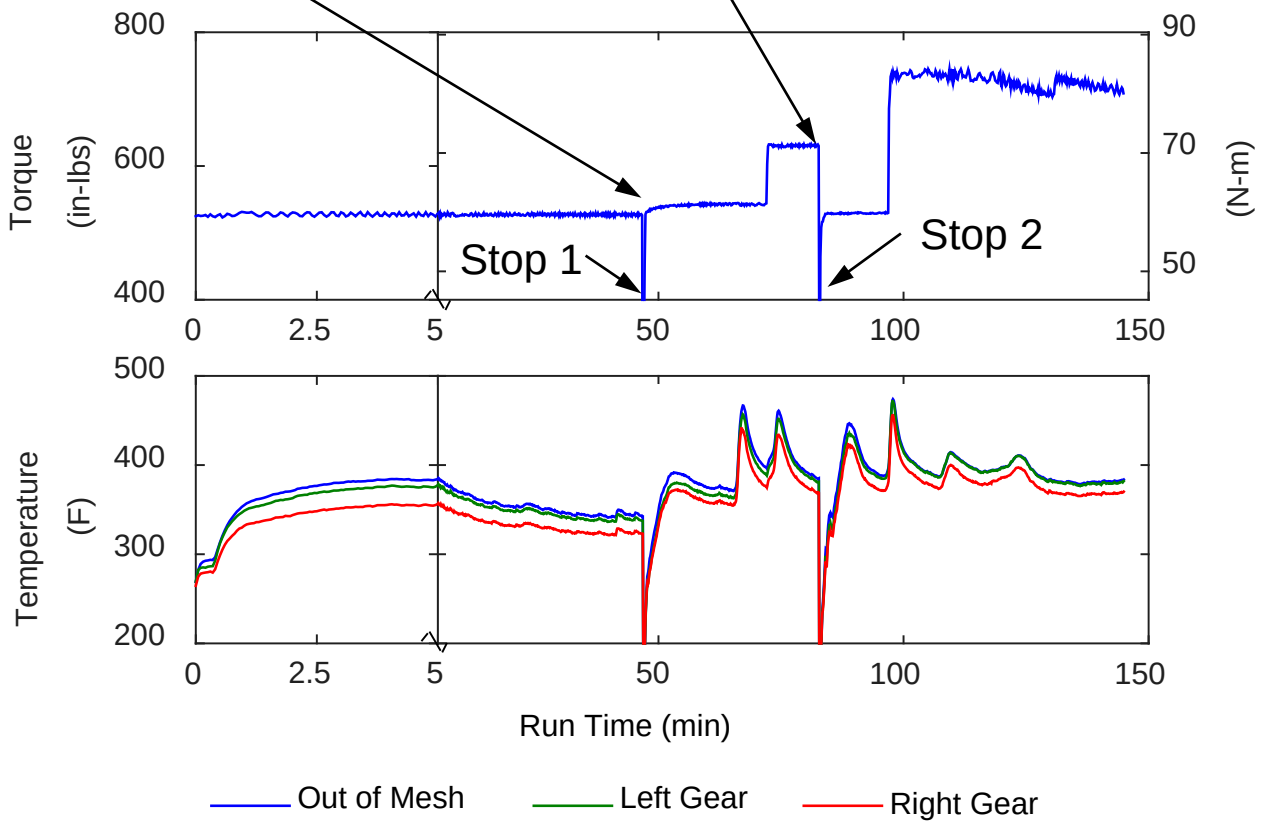
Results - Experiment 2



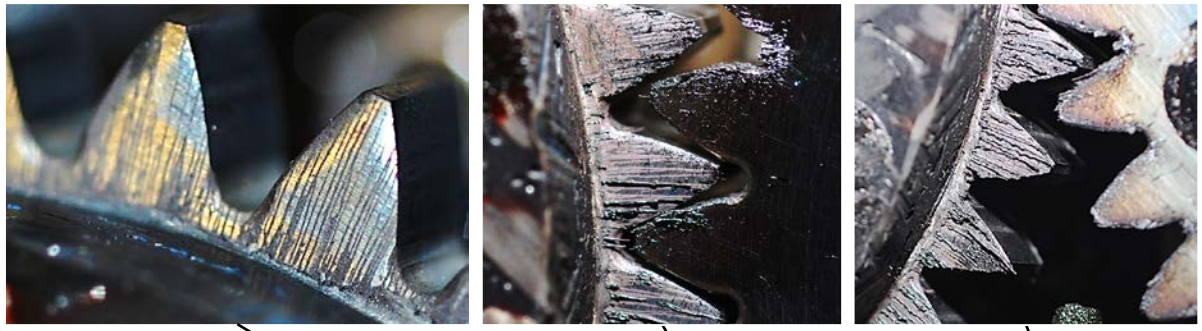


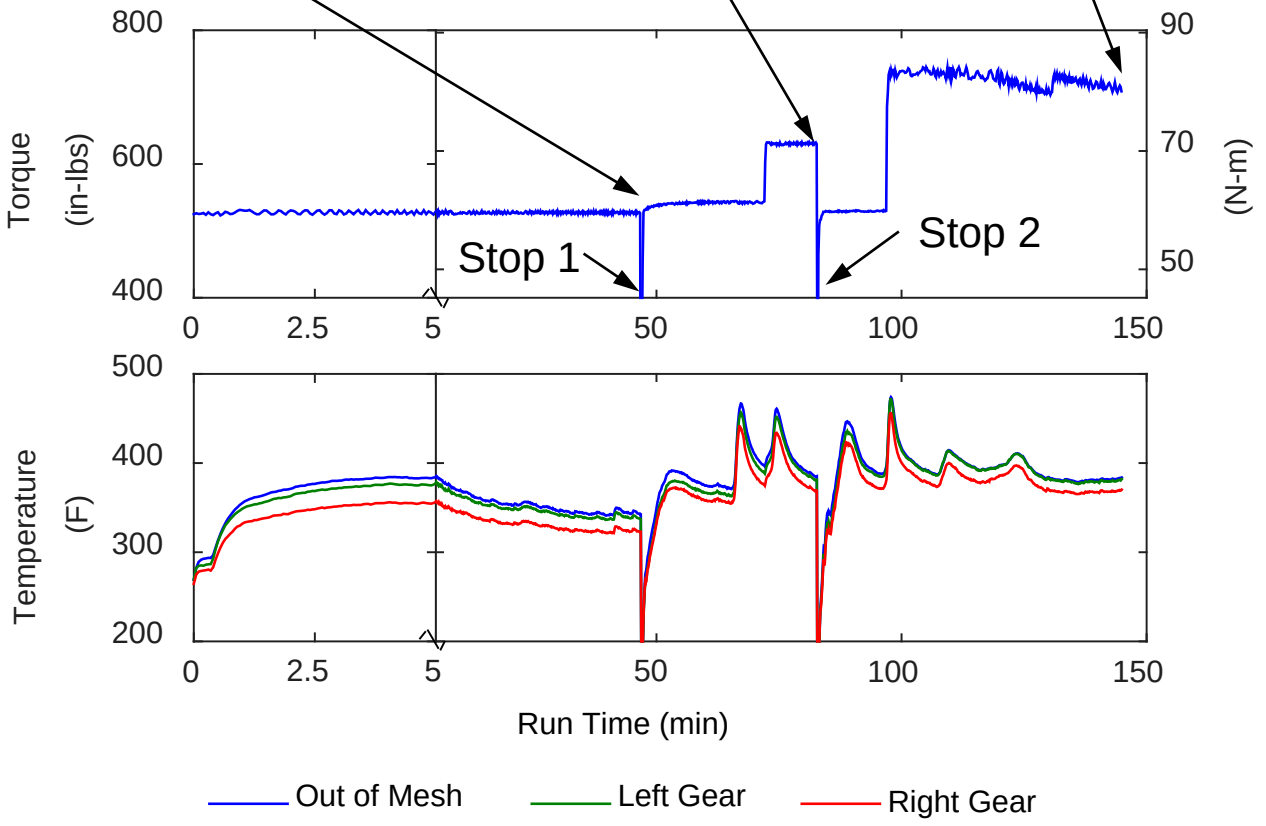
Stop 2

- Torque transfer verified
- Gears photographed
- Restarted experiment dry and reapplied load



Results - Experiment 2





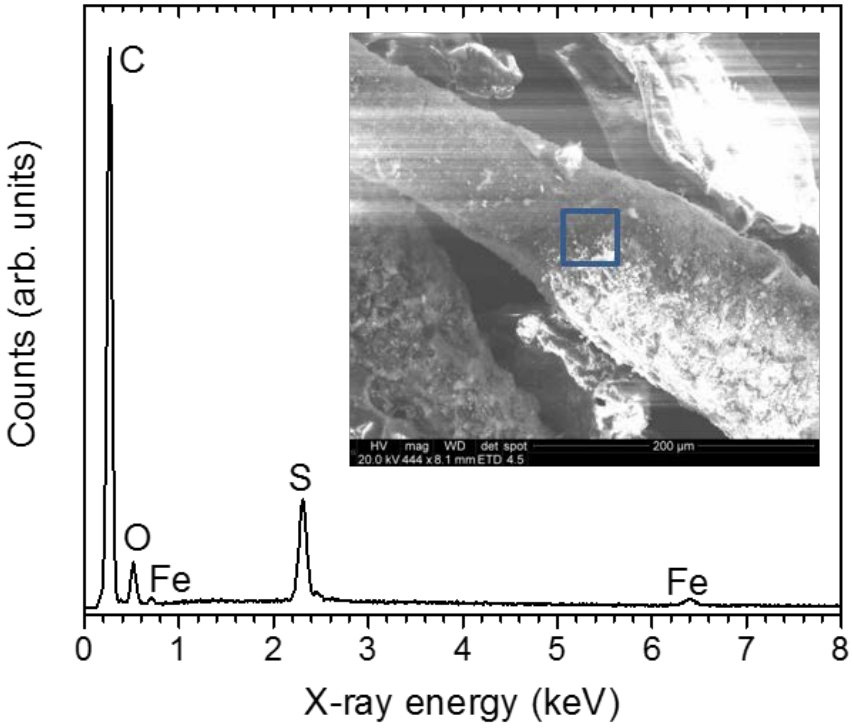
Post-test Analysis

What is the source of the black substance on the gear teeth?

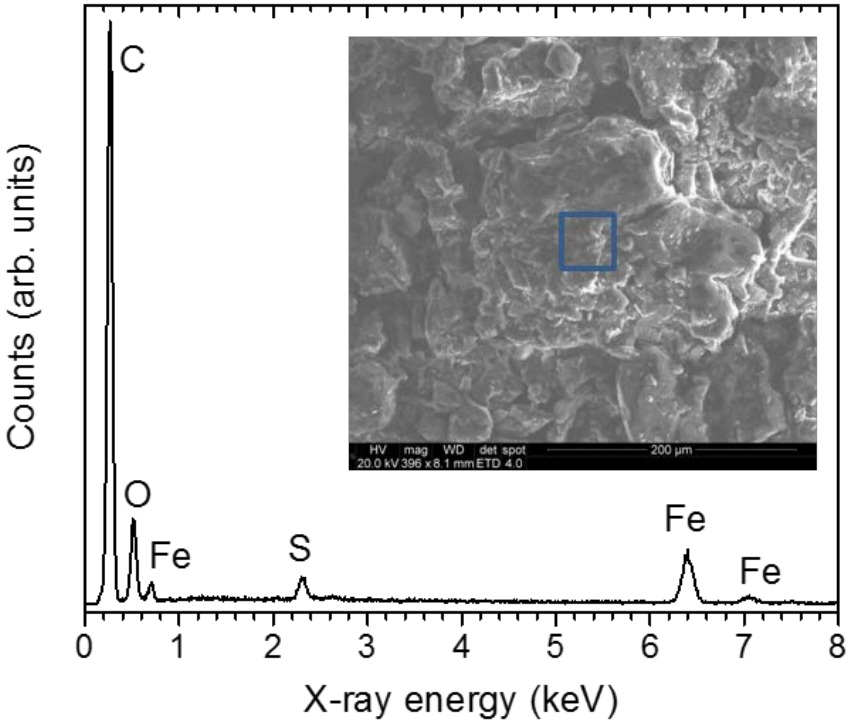
- Samples collected
  - Gear teeth
  - Gearbox
  - Uncured prepreg
  - Thin film adhesive
- Analyzed using energy dispersive spectroscopy for elemental characterization

EDS Analysis

Gear Tooth Surface Sample

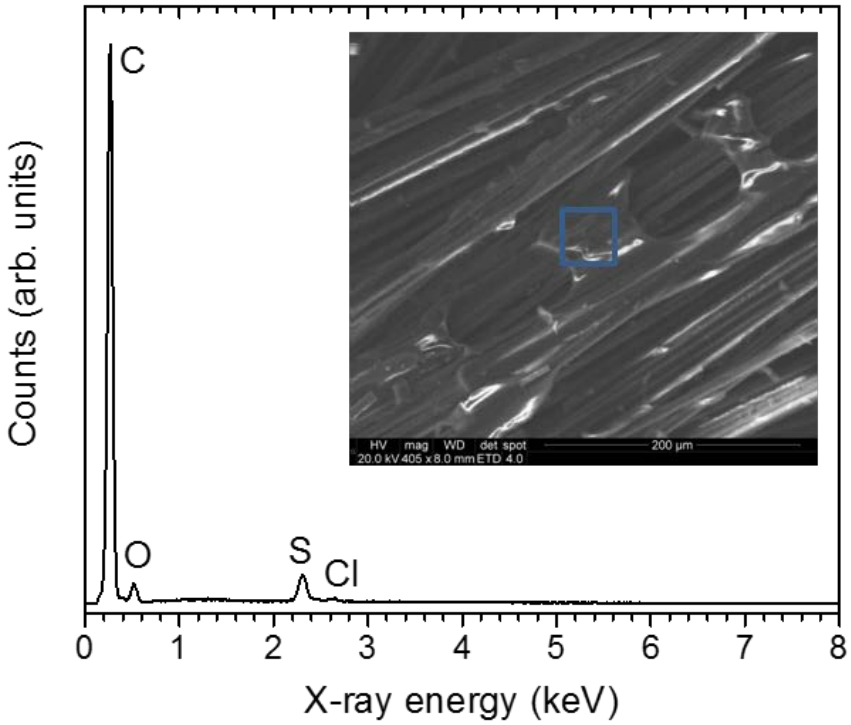


Gearbox Residue Sample

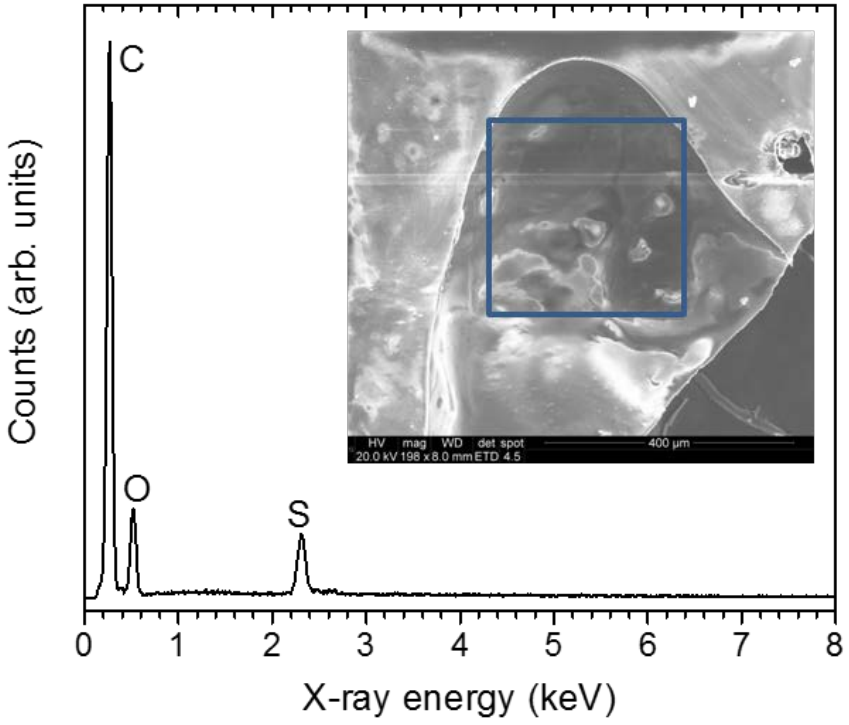


EDS Analysis

Epoxy on Prepreg



Thin Film Adhesive



Conclusions

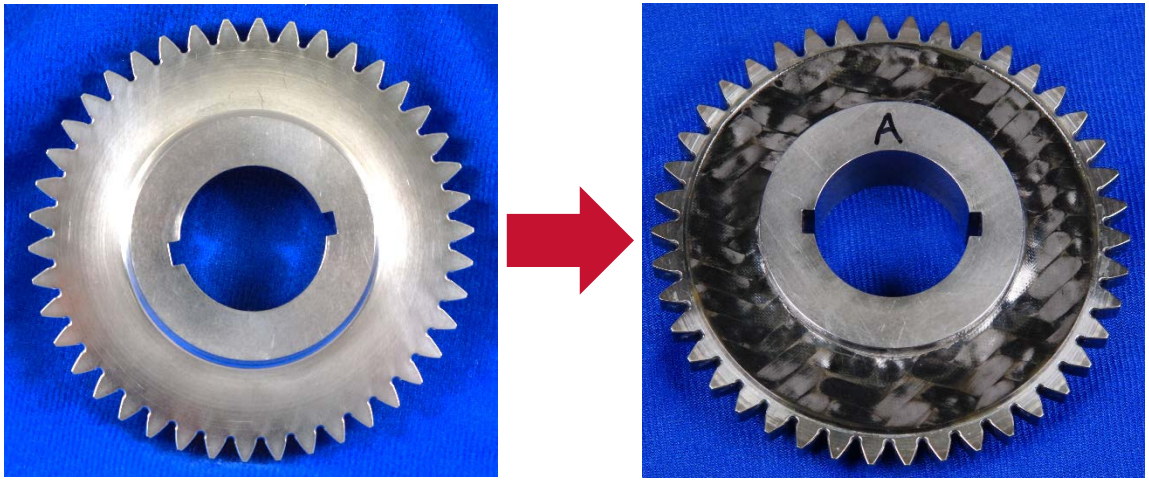
- **The mechanical interlock design in a hybrid gear is important during an oil-out event**
- **The pinned interlock pattern was shown to better withstand this type of event**
- **At increased temperatures, softened polymer at the gear mesh may act as a lubricant or sulfur-containing lubricant additive**

The effects of material degradation on hybrid gear design for oil-out conditions needs further investigation

Future Work

- **Isolate source of performance increase**
  - **Increased backlash**
  - **Polymer lubricant**

- **Can polymer flow phenomenon be used to increase survivability of steel gears during an oil-out event?**



Questions?

Acknowledgements:

- A&P Technology – Provided hybrid gears used for this project as part of a NASA SBIR
- Roger Tuck – Technician support
- ARL's Weapons and Materials Research Directorate – EDS