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Hybrid Gear Performance Under Loss- of-Lubrication Conditions

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



What is a hybrid composite gear?

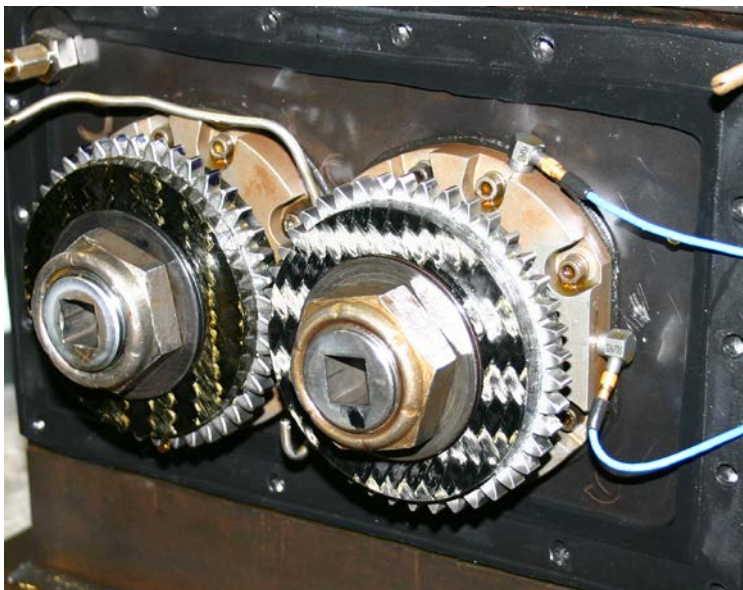
- **Hybrid composite gear replaces the structural steel portion of a gear with a lightweight composite material**

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**



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

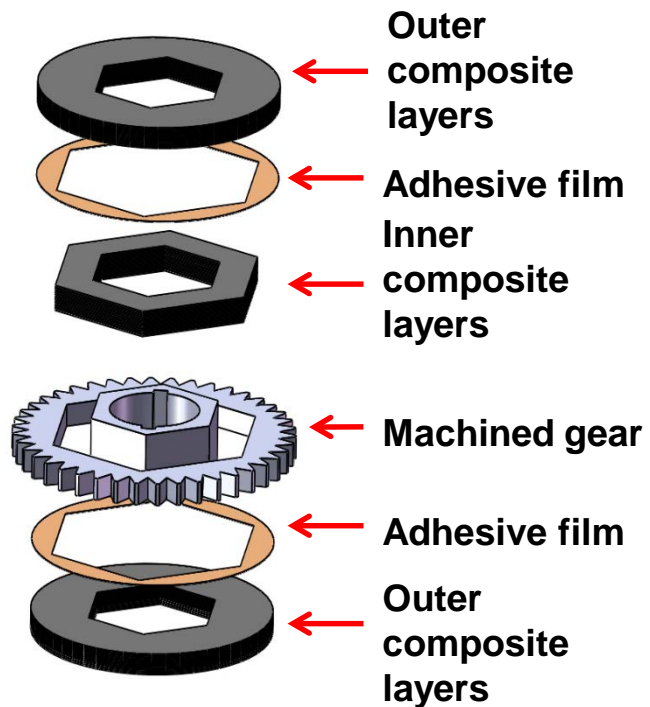
- One million cycle endurance test at 3300 hp
- Operational testing at 5000 hp
- Static torque test on the web



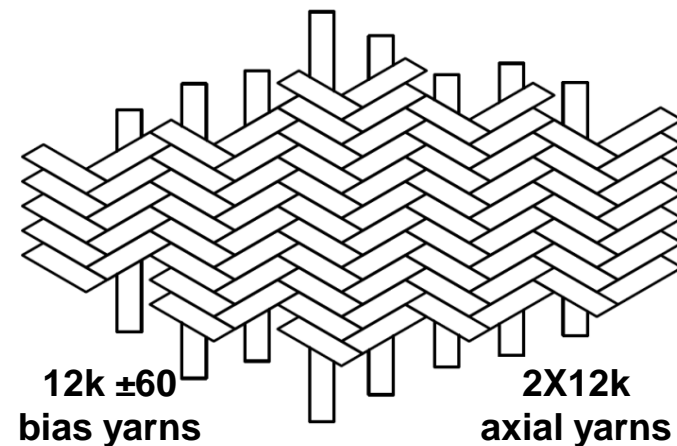
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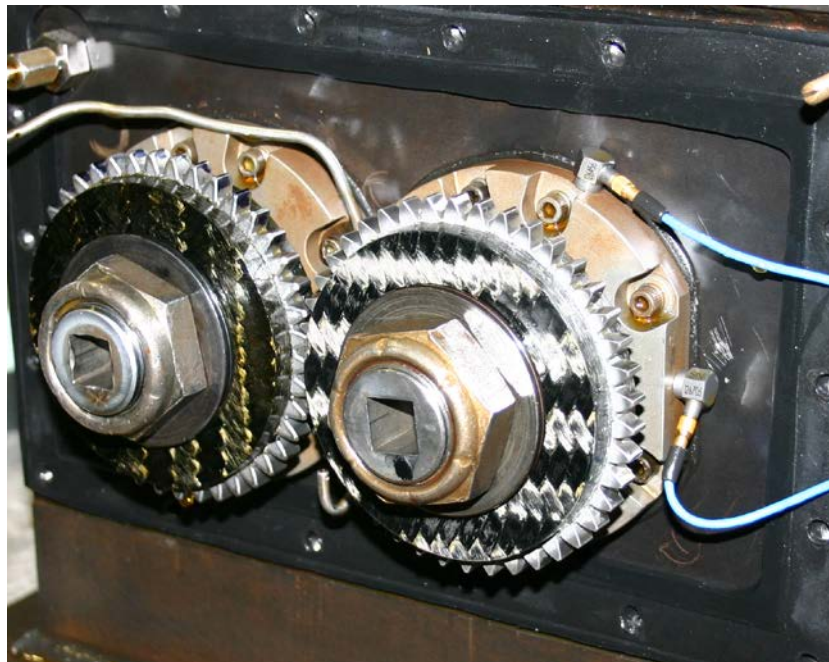
What about operation
under adverse
conditions?



Triaxial Braid Architecture



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

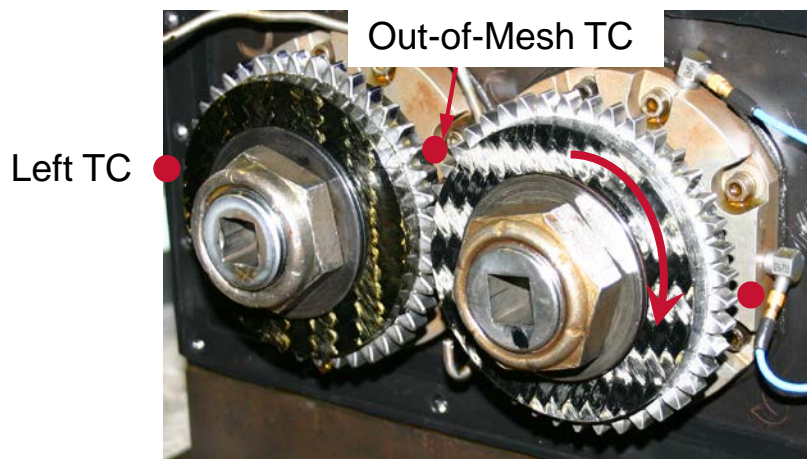
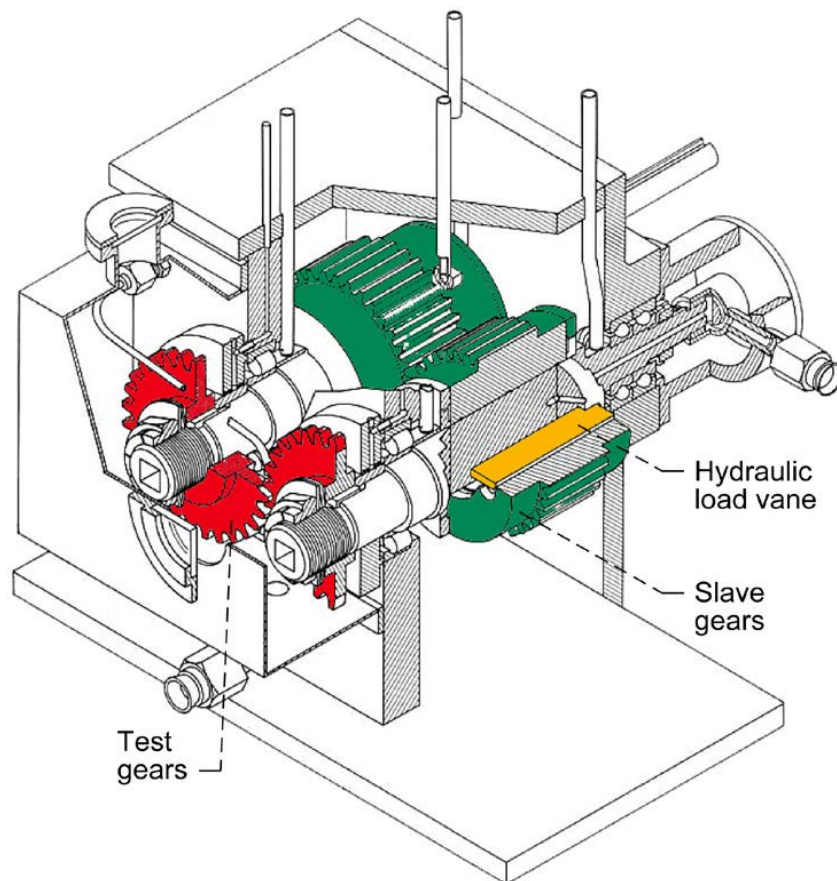


- Gears were reground to correct distortion caused by the curing process – **Resulted in increased backlash**
- Endurance test (10,000 RPM, 490 in-lb) completed to 10^9 cycles
- Two hybrid gears used, no damage detected after endurance test



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

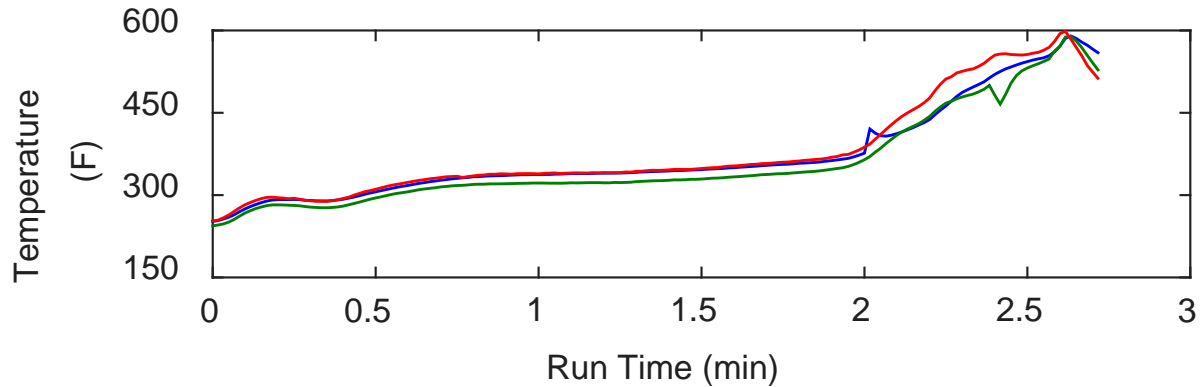


Right TC

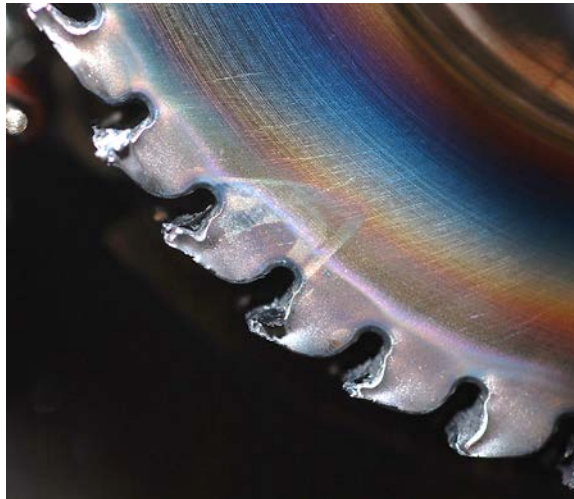
**Contact Fatigue Test Rig at NASA
Glenn Research Center**

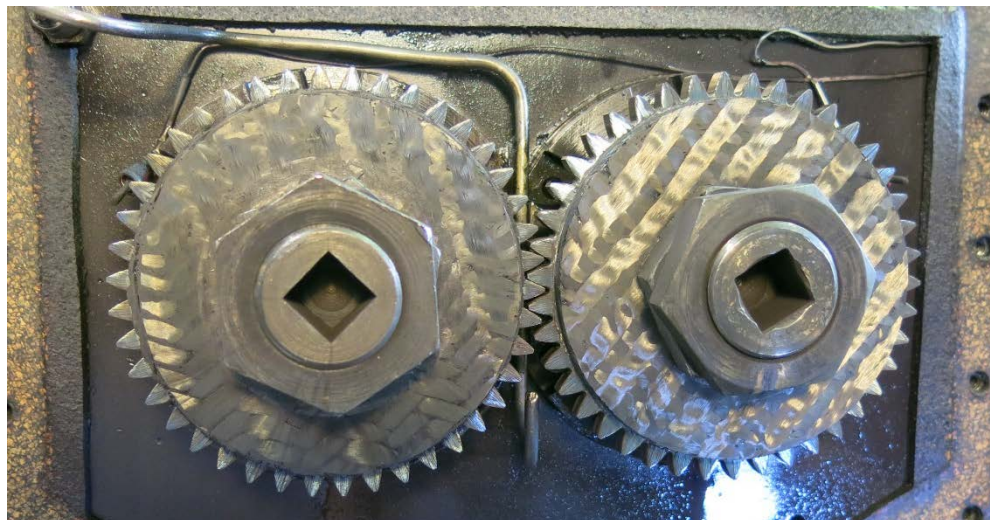
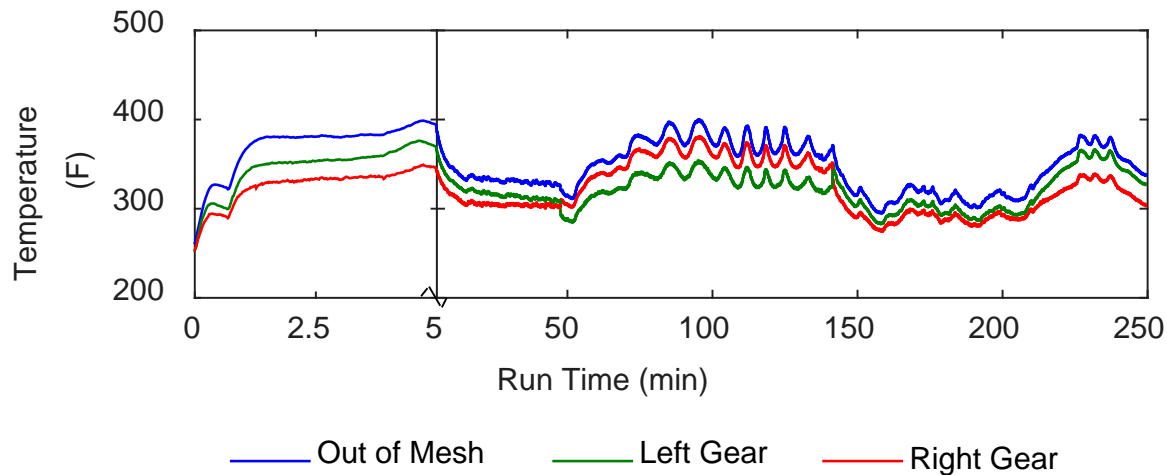


Steel Driving Steel (Unshrouded)



— Out of Mesh — Left Gear — Right Gear

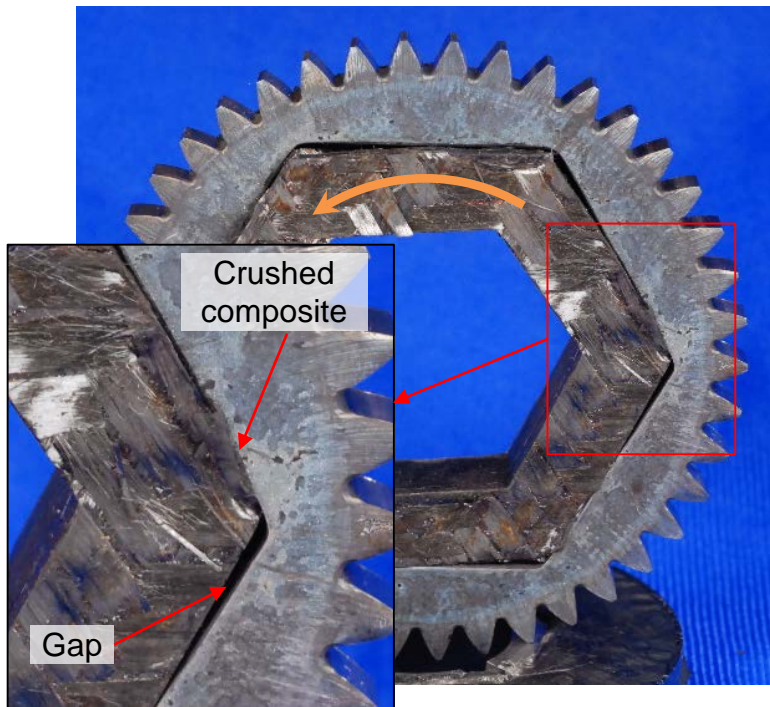


**Hybrid Driving Hybrid**

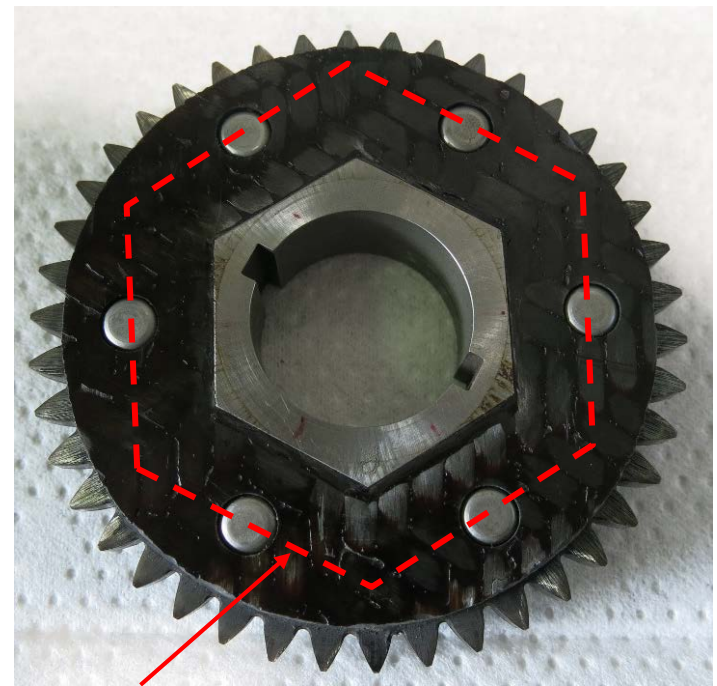
- After shutdown loss-of-torque was verified
- Visual inspection showed that the hub had rotated with respect to the teeth on the left gear



Disassembled left gear



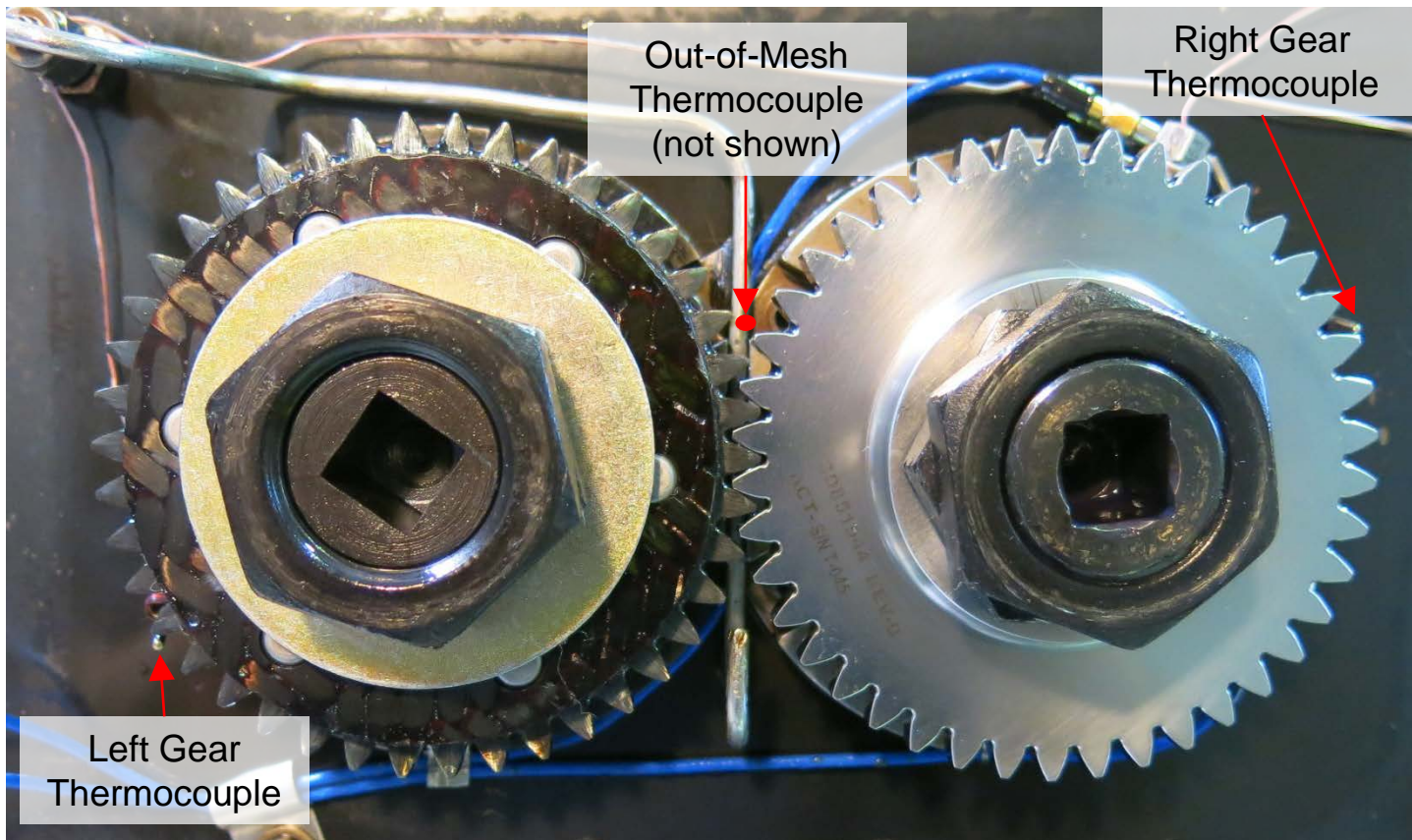
Modified right gear

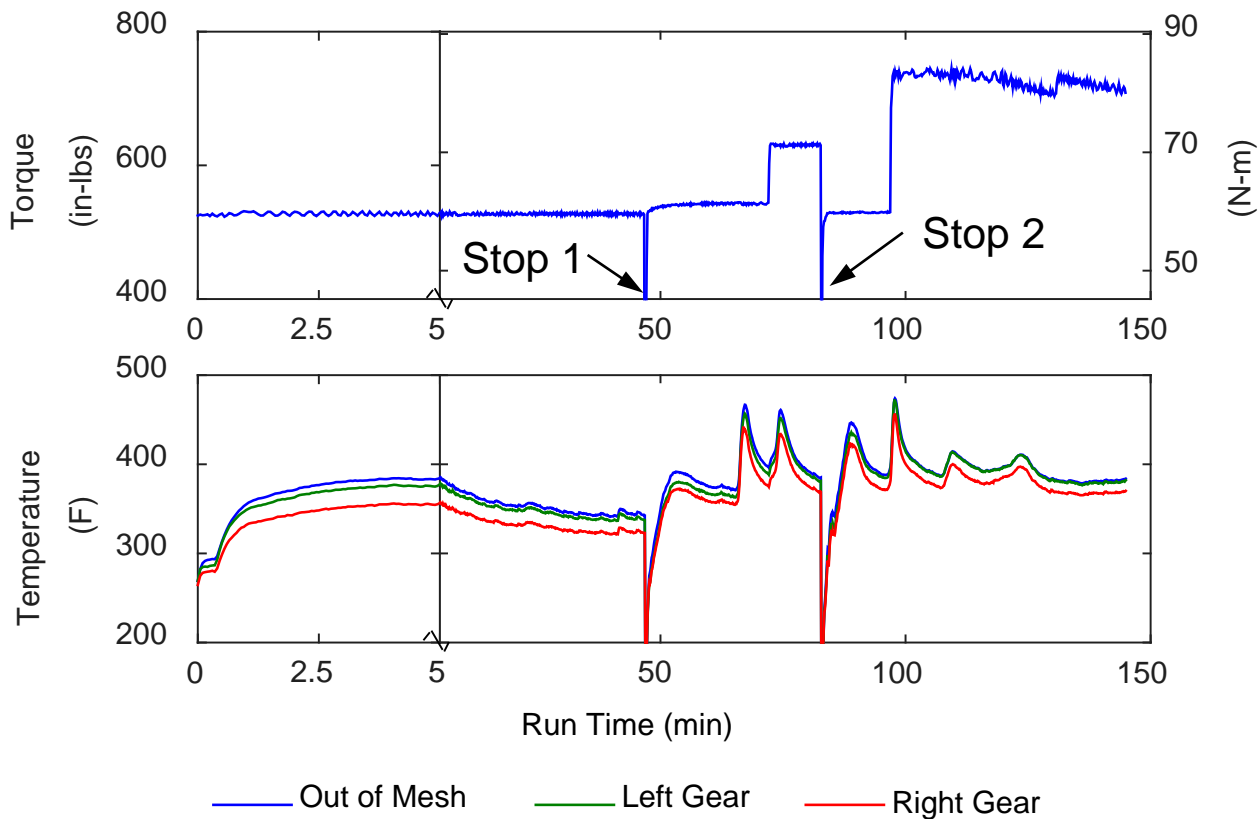


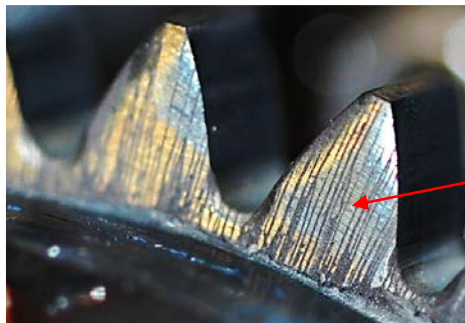
Approximate location of interlock pattern



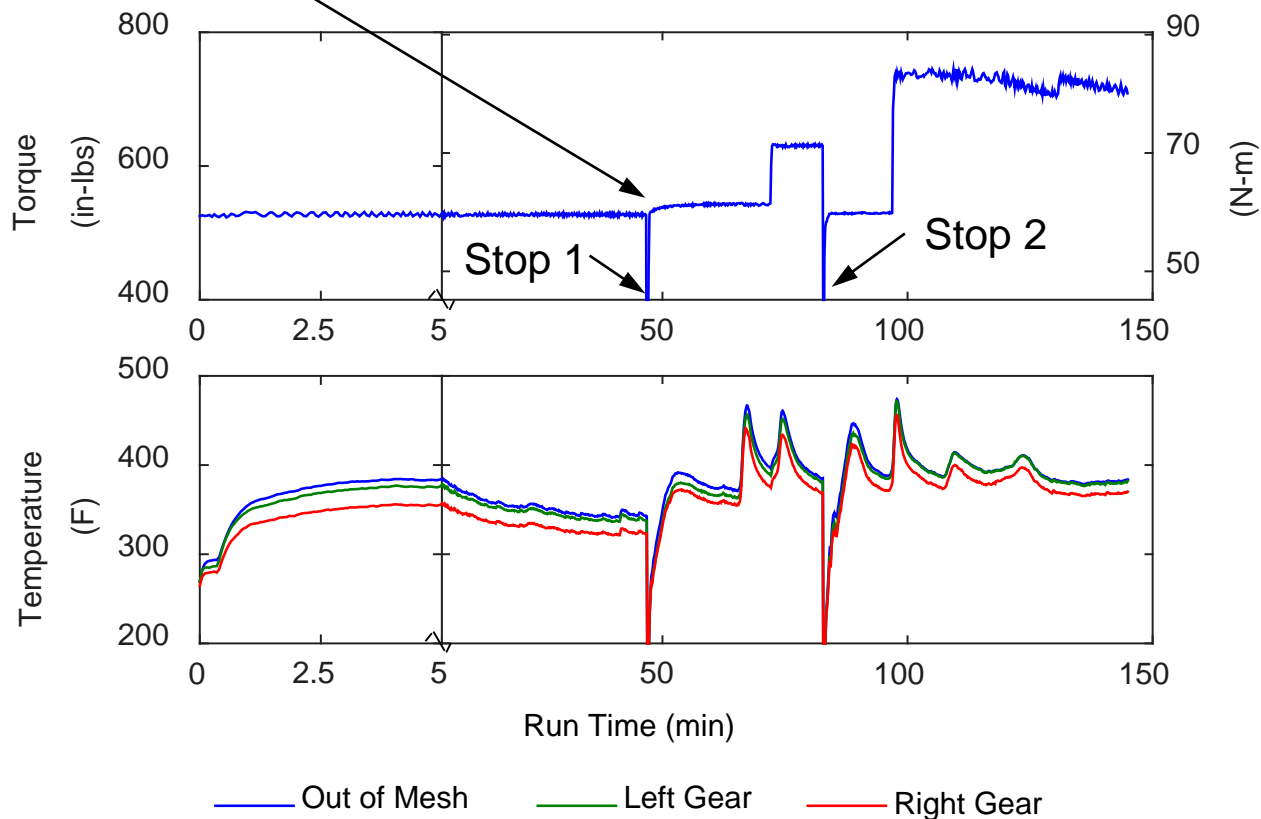
Experiment 2

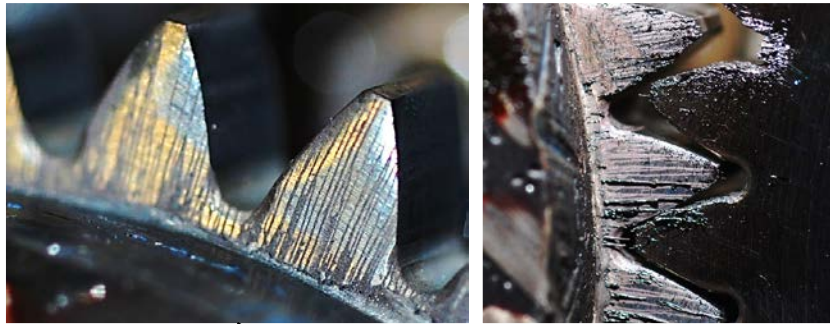




**Stop 1**

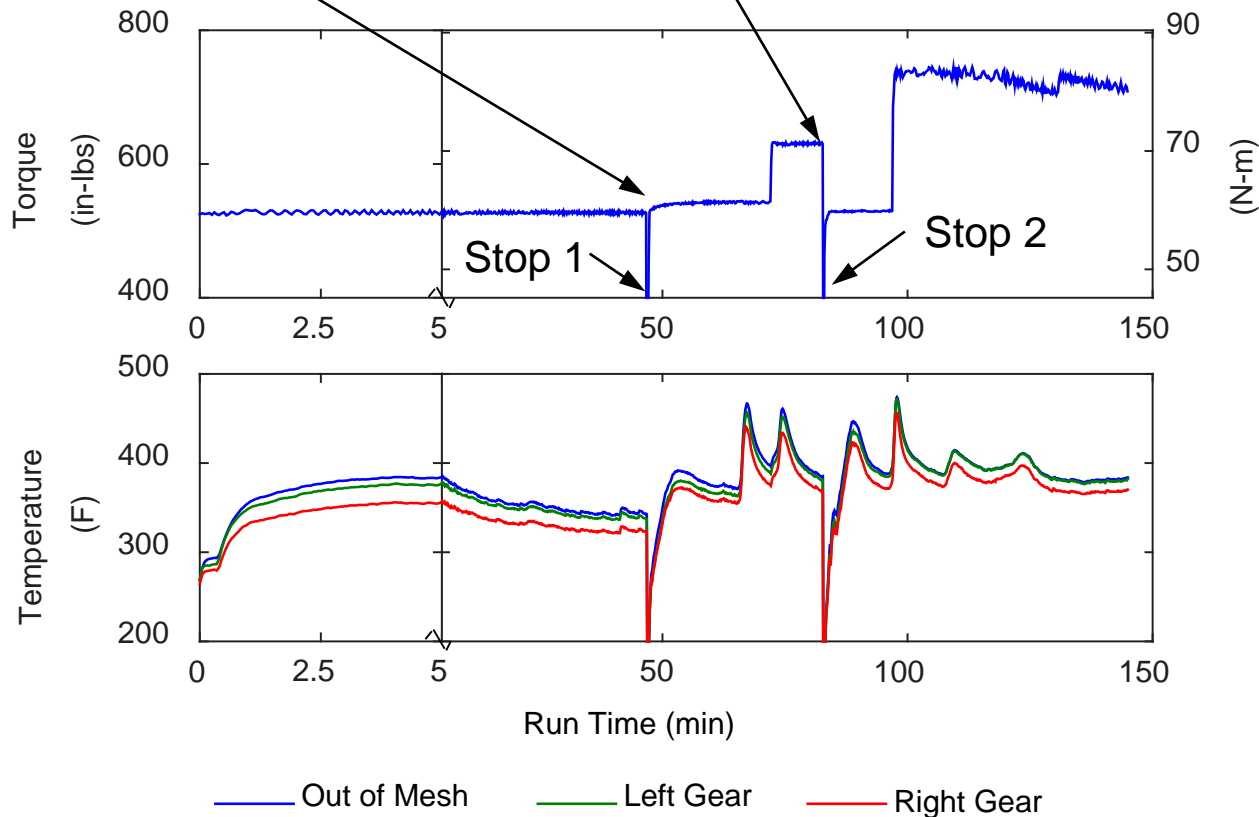
- Torque transfer verified
- Black lines documented on teeth
- Restarted experiment dry and reapplied load





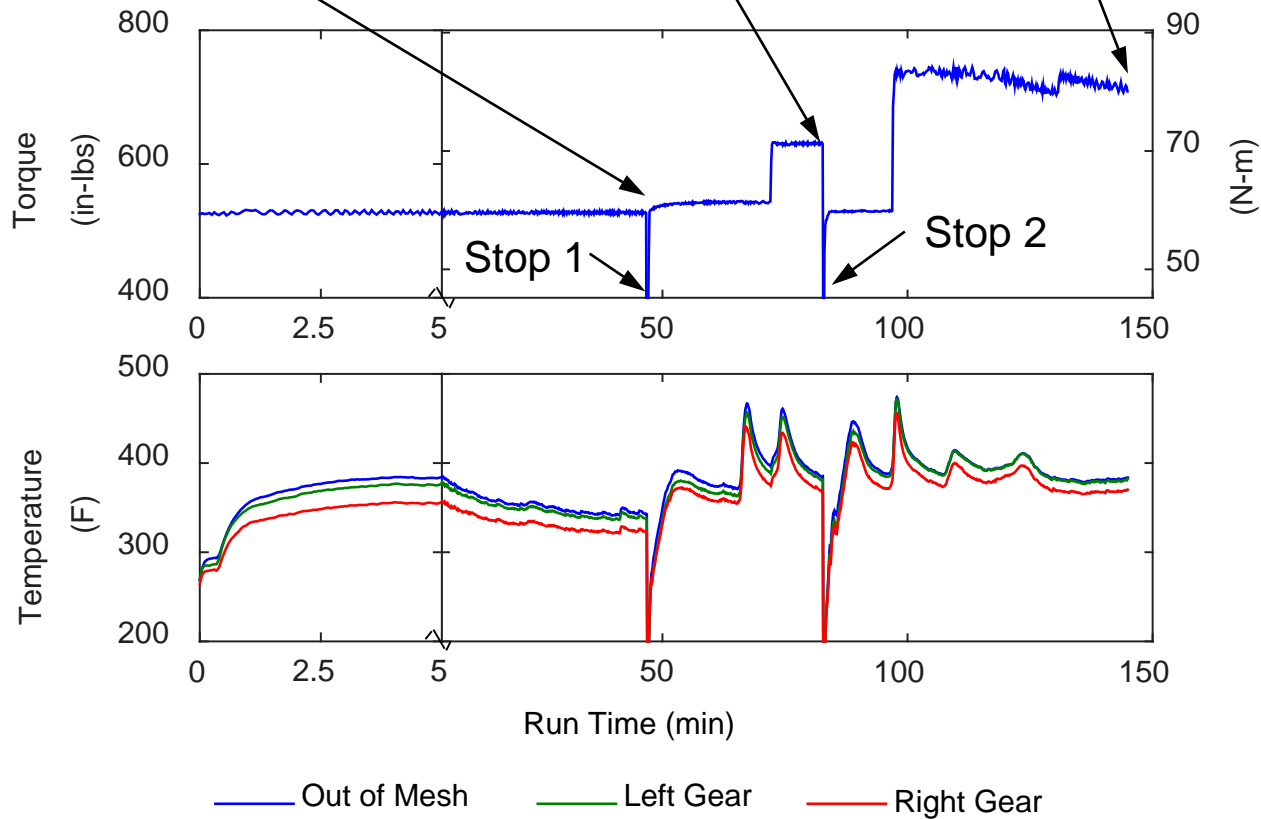
Stop 2

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





Results - Experiment 2





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

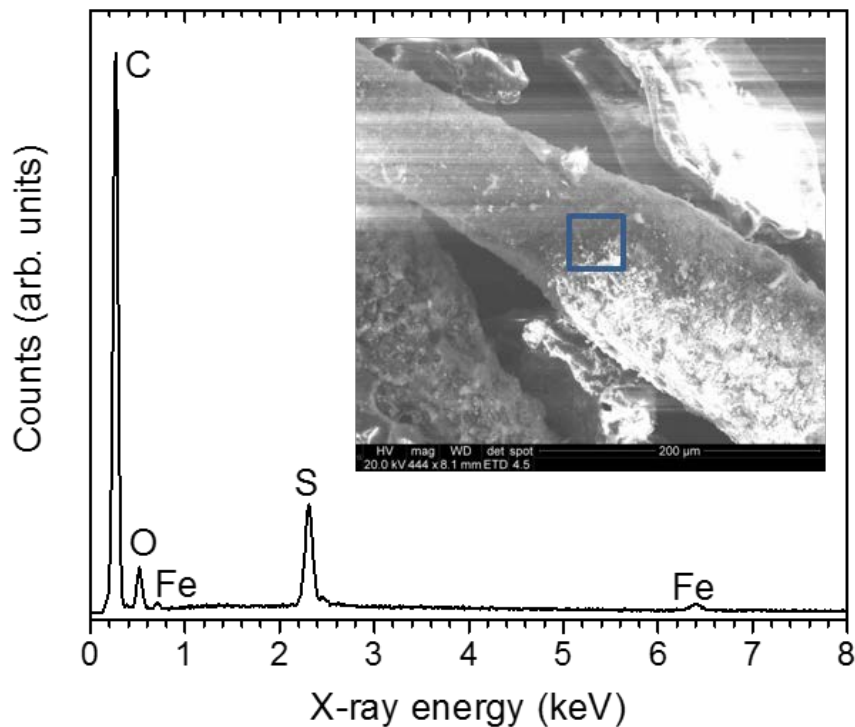


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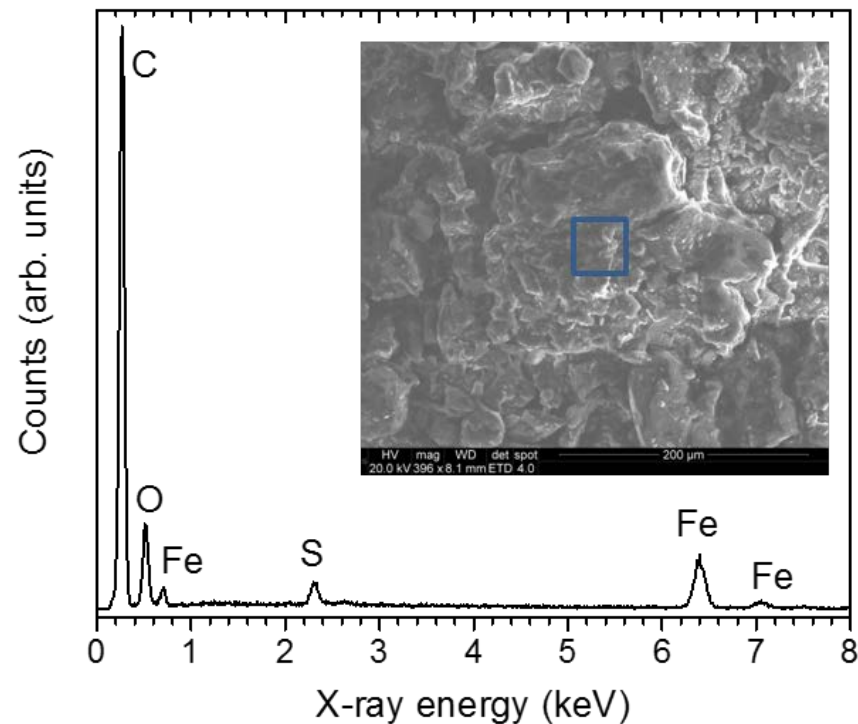
EDS Analysis



Gear Tooth Surface Sample



Gearbox Residue Sample



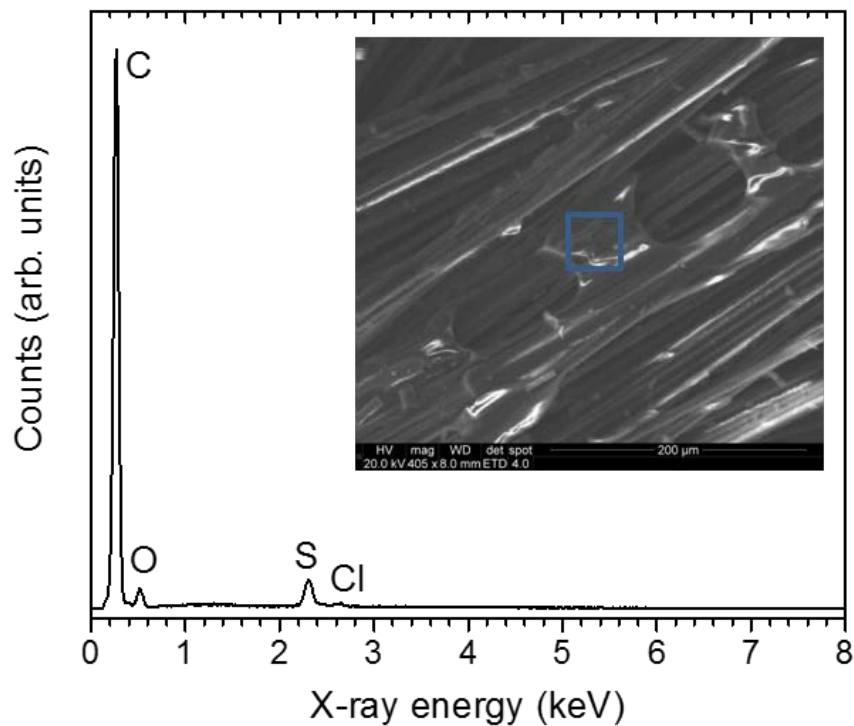


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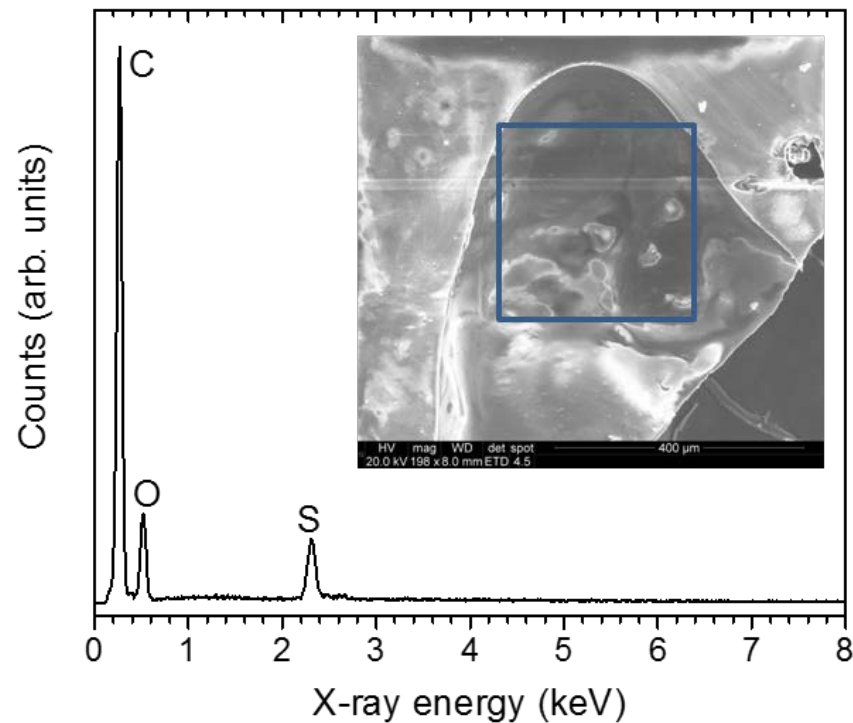
EDS Analysis



Epoxy on Prepreg



Thin Film Adhesive





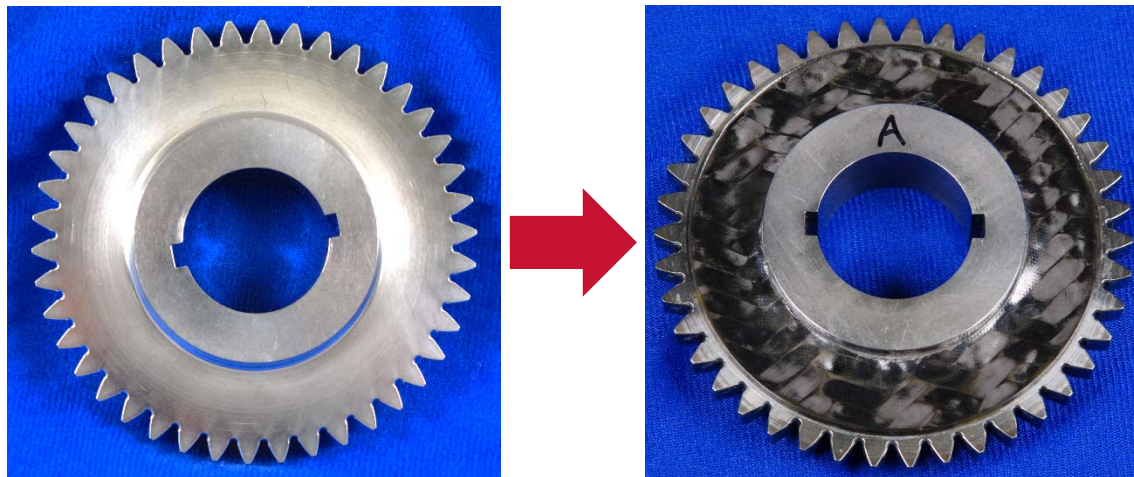
- **The mechanical interlock design in a hybrid gear is important during an oil-out event**
- **The pinned interlock pattern was shown to better withstand this type of event**
- **At increased temperatures, softened polymer at the gear mesh may act as a lubricant or sulfur-containing lubricant additive**

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



- **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?**





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Questions?



A&P Technology



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