Inconel X-750 Spacers Removed from CANDU Reactors for Surveillance

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Life Cycle Management for CANDU Reactors

- Inconel X-750 spacers
  - core component serves 25+ years in CANDU
  - periodically removed for surveillance
  - 1 coil ~4000 R/hr near contact
  - requires hot cell examination & testing to confirm fitness for service
The Spacer

- Inconel X-750 spring
- Zircalloy-2 girdle wire
- ID ~108 mm
- Coil OD ~5 mm
- Square wire .76 mm
- Tight fitting to the fuel channel
Two Operating Temperatures

- Hot Pressure Tube (PT)
- Cold Calandria Tube (CT)
- Cold portion pinched between PT and CT
- Hot non-pinched region
- Test samples from two different operating temperatures
Material Receipt

- Removed from reactor
- Shipped to Chalk River on end fitting
- Placed in unique packages
- Orientation maintained
Fuel and Materials Cells

- Inlet face marked with paint
- D SLR images of both sides
- Inspection of the overall condition
- Coils counted
Pitch Measurements

- Video images using carousel
- **Non-pinched** = 13 coils/inch
- **Pinched** = 15 coils/inch
For this configuration:

\[ \text{Weight supported by spacer} \approx 2\pi T \mu \]
where \( T \) = spring tension and \( \mu \) = coefficient of friction

Since tension is simply proportional to weight, extrapolate diameter to zero weight to get diameter at zero tension.
Cutting the Hooks

- Hooks are cut using side cutters.
- Girdle wire is carefully threaded out of the spring.
Imaging of the Girdle Wire and Spring

Girdle Wire

Spring
Spacers with hooks cut and girdle wires removed.
Rolling of the spacers, simultaneous with stress relaxation, will cause a straightening of the spring.
• Spacers nearest to fixed end roll less & stay more round.
• Spacers nearest to free end rotate more & open up.

Stress relaxed shape helps to confirm axial location/order of spacers.

Also confirms spacers are rolling as per design intent.
Marking Sample Orientation

- Samples are marked to ensure the orientation is retained after sectioning.
- All coils are tracked and accounted for
Macroscopic Imaging

- Each section is imaged with a high resolution optical macroscope.
Mounting and Sectioning

- 2 coil samples are mounted for sectioning
Metallographic Samples

- Cross section imaging
- Dimensioning
- Microhardness testing
Crush Testing

• Specially designed rig is used to test the material.
Shielded SEM

- Single coil samples are produced from post crush test samples.
- Standard fractography is preformed.
Sample Sizes must be reduced before removal from the hot cell

1) Face is squared off
2) .45 mm thin slices are cut.
3) 1.5 mg samples are produced.
FIB Sample Prep

Samples are mounted, ground and polished in the hot cell.

1.5 mg sample is attached to an SEM stub ground and polished.

Prepared sample imaged by microscope

Stub removed from grinding block then removed from the hot cell
Small Scale Mechanical Testing (SSMT)

- Samples sent to the FIB to be prepared for small scale mechanical testing (SSMT).
Thank you! Kiitos!

Questions?

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