Rotating Balance Design Methodology

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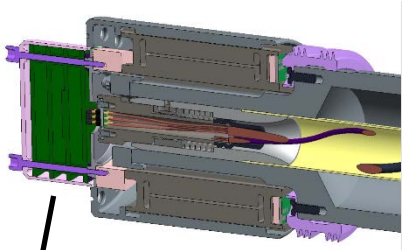
AIAA SciTech 2021
Virtual Event

Motivation

- Force balances provide a measure of propulsion performance independent from flow field measurements.
  - System performance (net thrust – drag) is only measured with force balances.
  - Fan efficiency measurements based on rotor torque are more accurate than pressure/temperature based measurements.
- New two-component rotating balances are being required for the testing of fan concepts being developed under several NASA Aeronautical Research Mission Directorate (ARMD) projects
  - Higher bypass ratio fans with smaller engine cores (GRC-517Rs)
  - Boundary layer ingestion tolerant fans (GRC-419R)
  - Hybrid electric propulsion concepts (tail cone thruster, etc.)
- Need to interface to new state-of-the-art FPGA telemetry systems that have been developed for fan testing at NASA GRC

Current Need

Blue = Rotating Balance Metric



2-Component Rotating Balance

Light Gray = Static Balance Metric

Static (Cowl) Balance MC-129-8.55A

Dark Gray = Non-metric

Typical Turbofan Test Rig

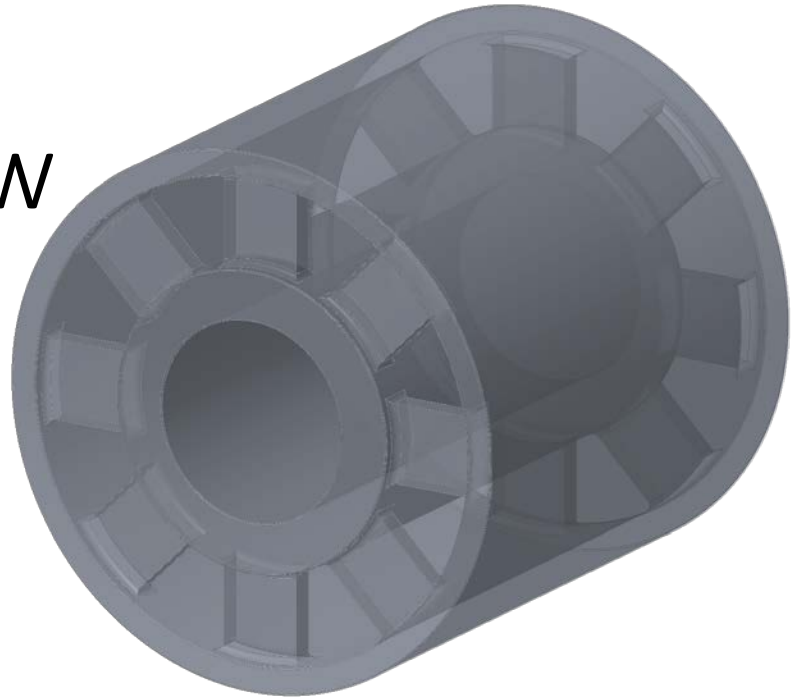
New Rotating Balances

Three (x3) new rotating balances are in various stages of design and production

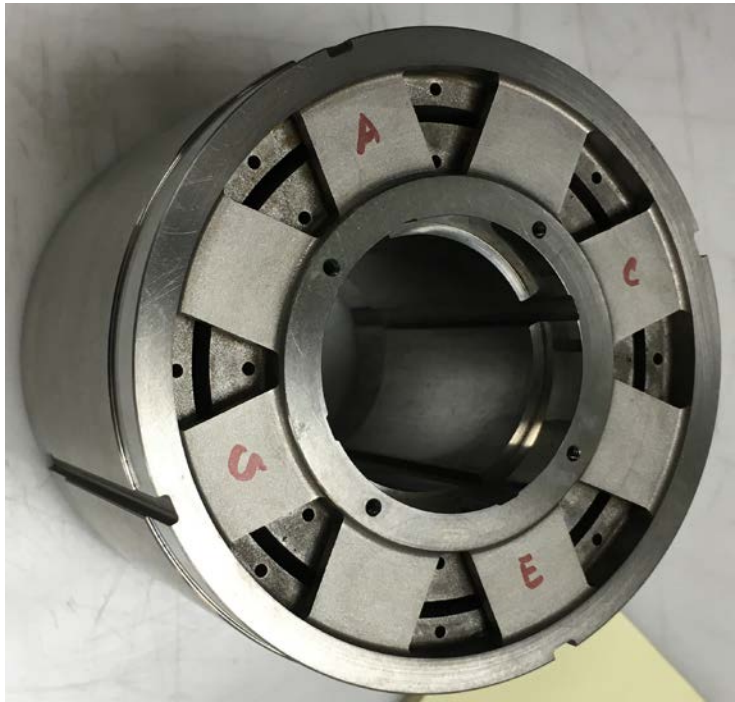
- (x2) Two-component small form factor rotating balances (GRC-517R-A&B) for advanced turbofan testing at NASA Glenn Research Center

- (x1) Two-component rotating balance (GRC-419R) for boundary layer ingestion testing at NASA Glenn Research Center

Rotating Balance Design Overview



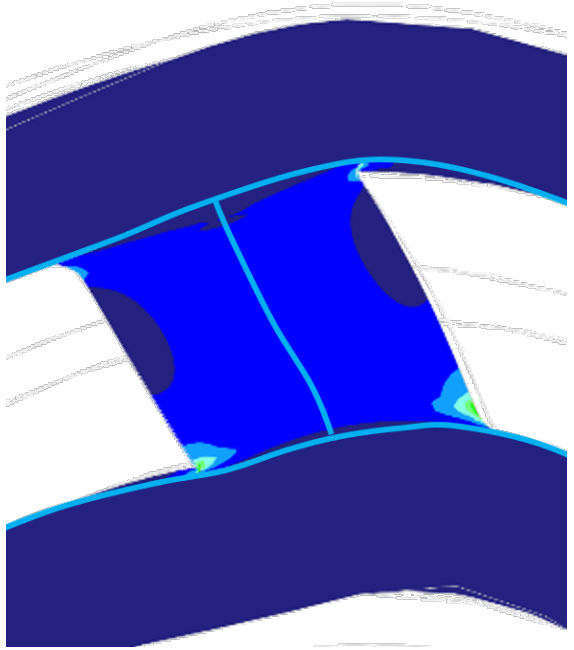
- Spoke wheel design, with both forward and aft beam groups
- Two measurement components:
  - Torque and Thrust
- Thick “bulkhead” behind beams
- Keyways to transmit torque loads

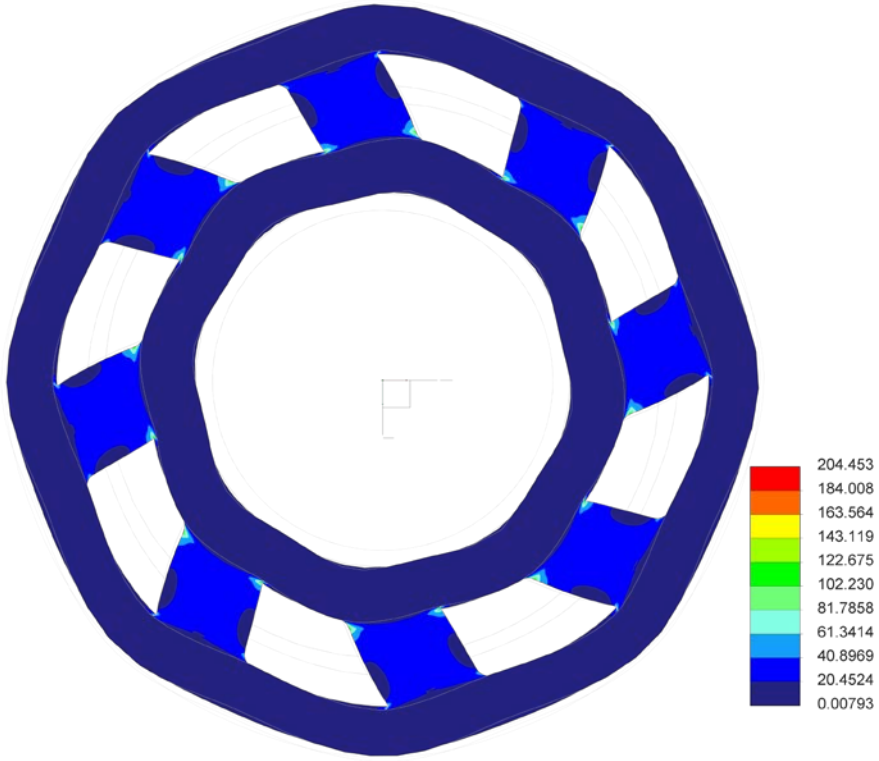


Finite Element Analysis Observations

- Double bending behavior was initially expected due to torque load

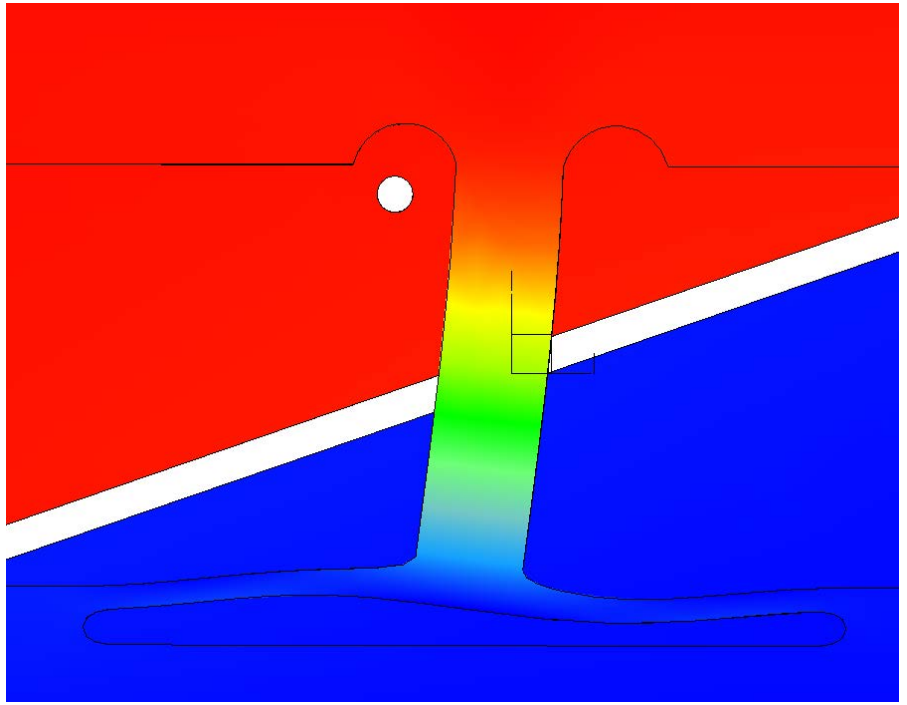
- FEA revealed warping behavior of the outer and inner diameters
  - Warping of outer diameter reduces double bending behavior of beams

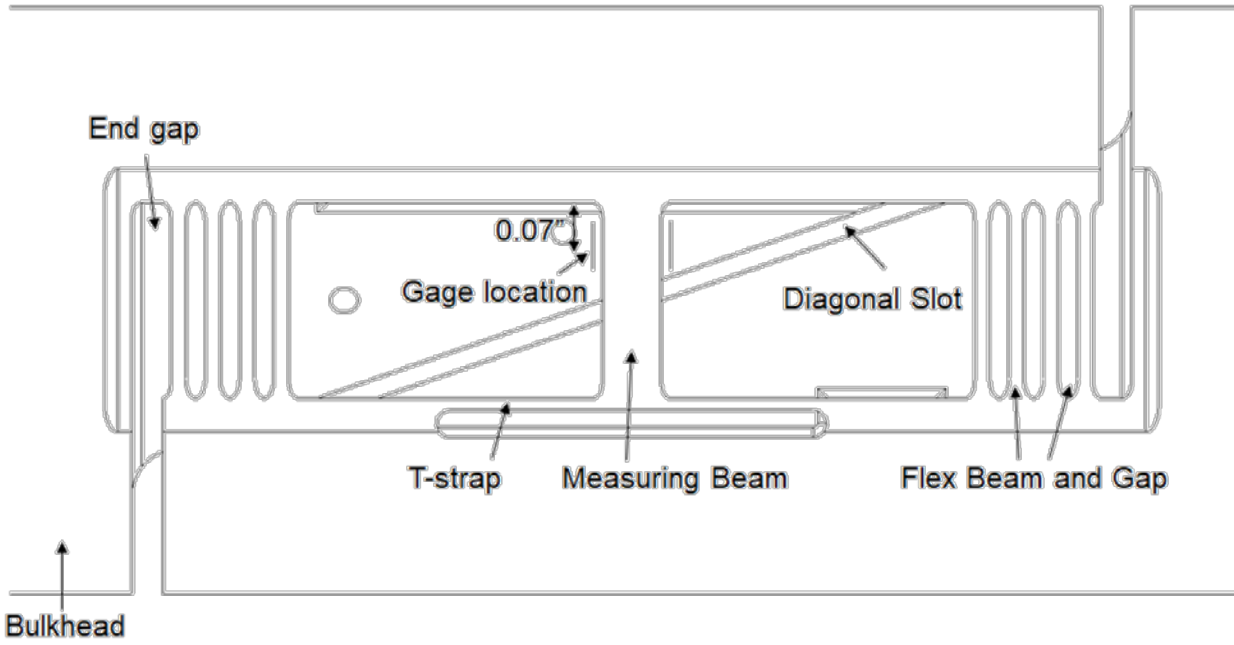




Analytical Model – T-Strap

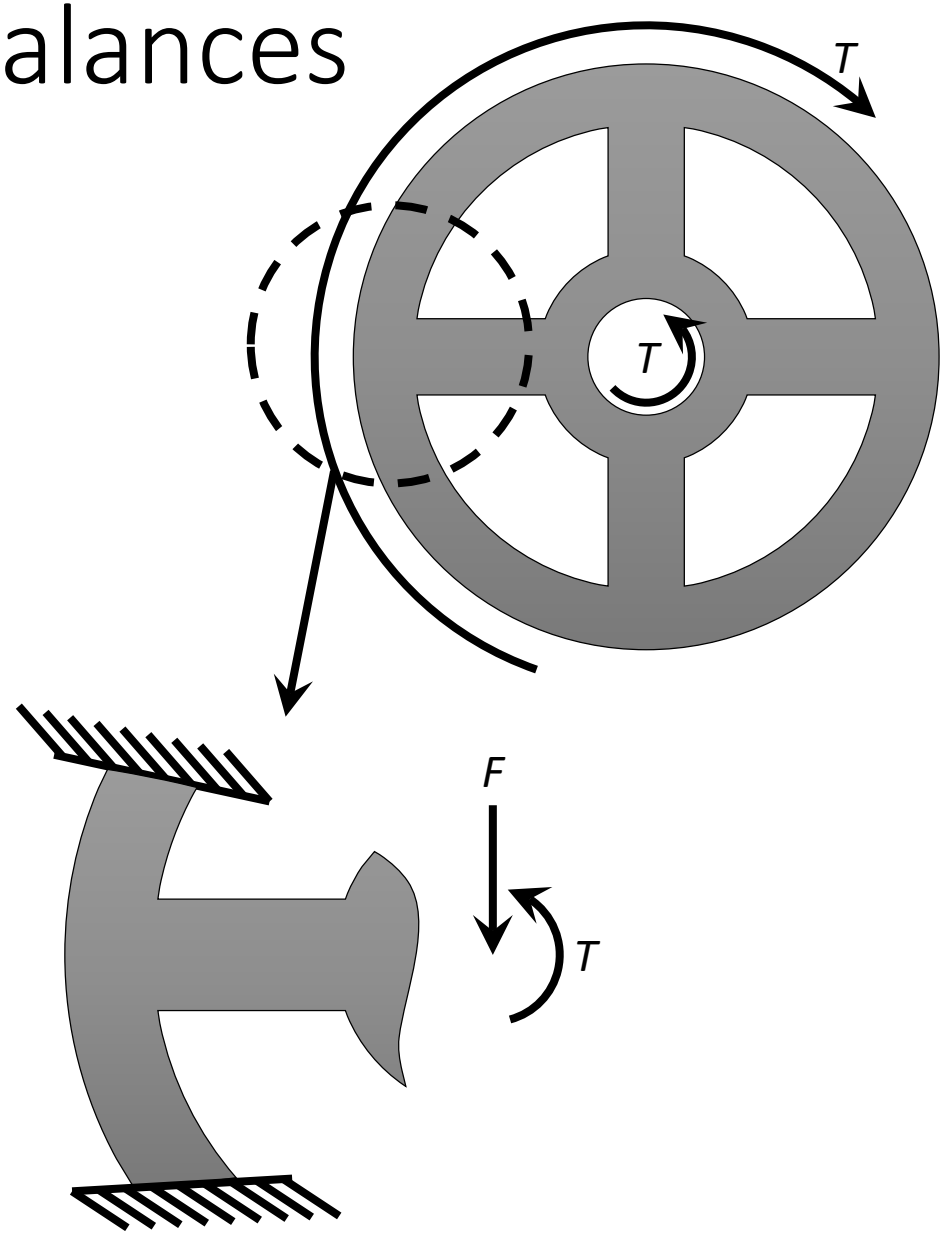
- Behavior of the outer diameter is similar to another known balance feature, the T-Strap
- A T-strap is a design used to reduce normal force interactions on the axial measuring beam
- This design feature reduces the double bending of the axial beam
- See NASA/TM–2019-220248 for more details





T-Strap Applied to Rotating Balances

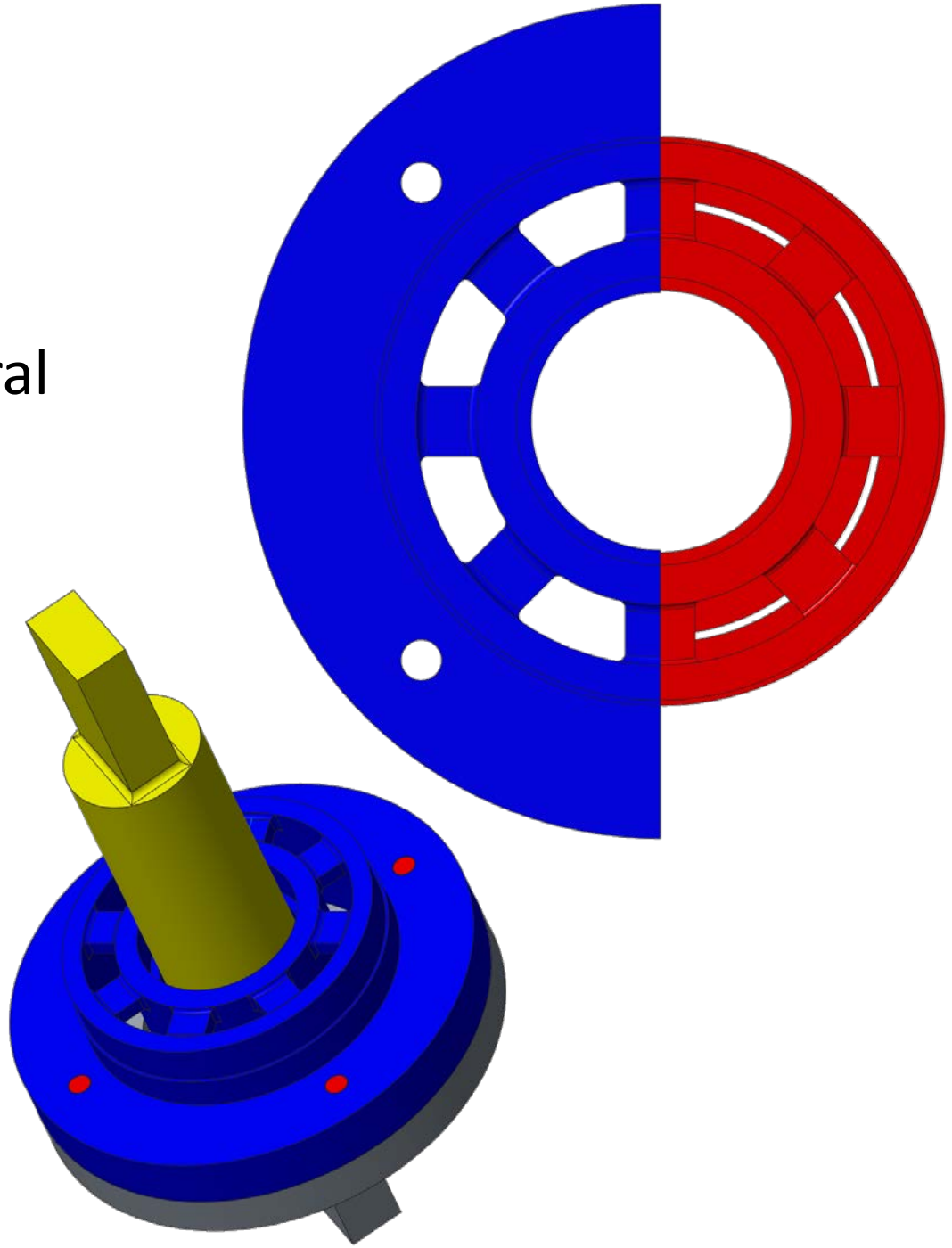
- A single spoke of the rotating balance can be viewed as a T-Strap
- Modification to the T-Strap calculations involves reevaluating the derivation to include torque at balance center
- Assumption is made on effective strap width



Model Validation Study

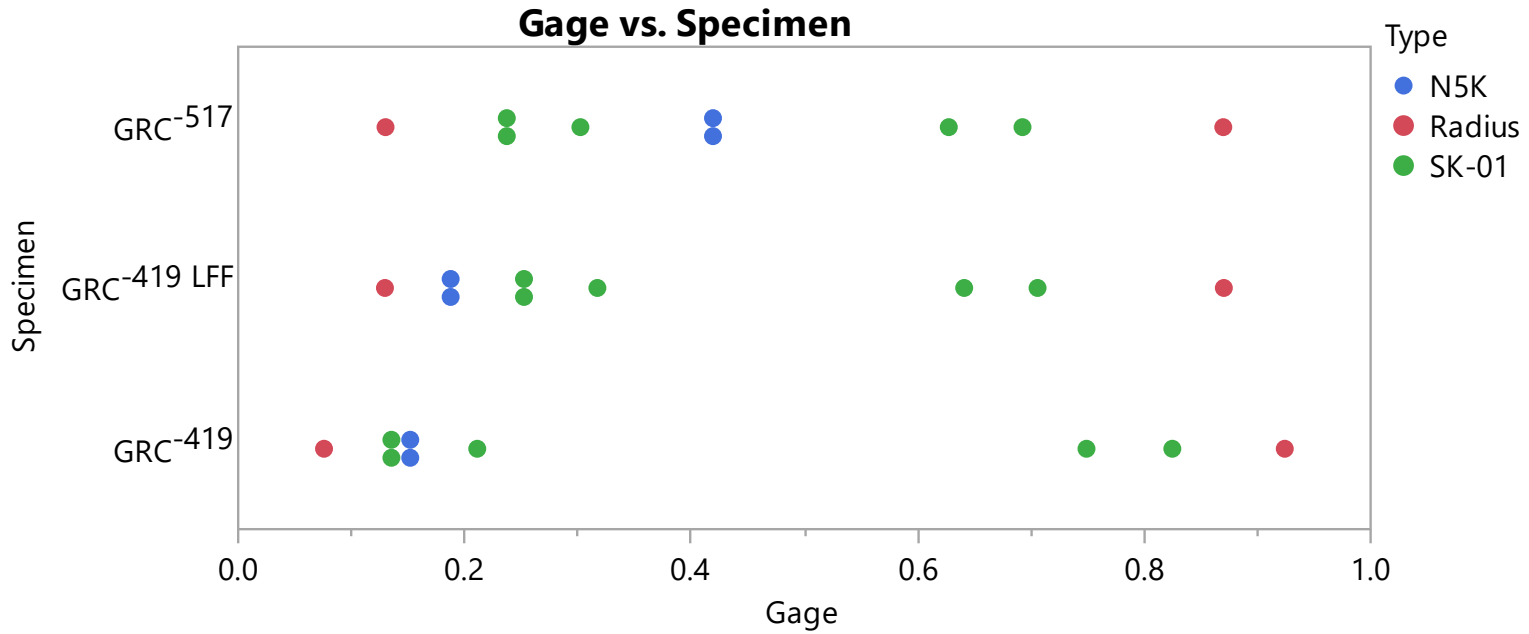
- Validation study was conducted on several designs
  - 517R
  - 419R
  - 419R Low Form Factor (LFF)

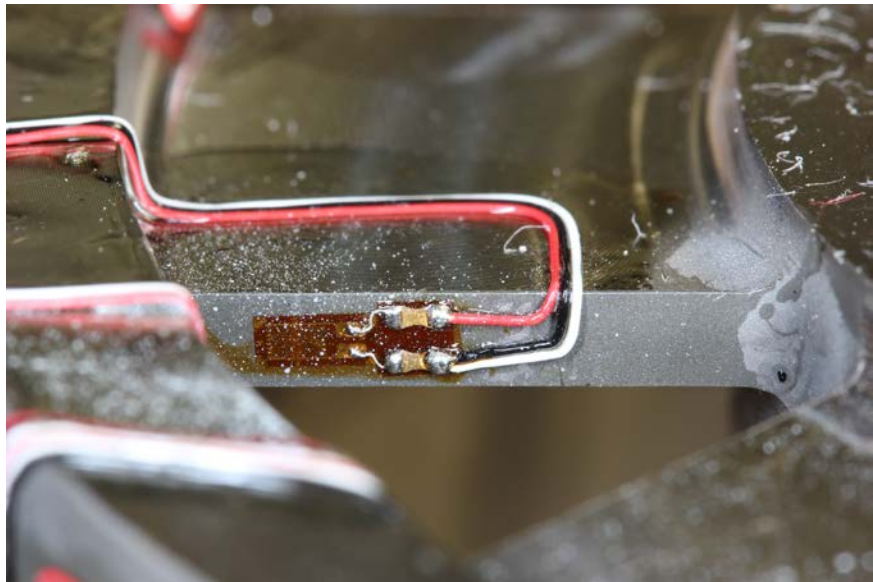
- Test assembly featured exchangeable specimens and reusable fixture points



Test Specimens

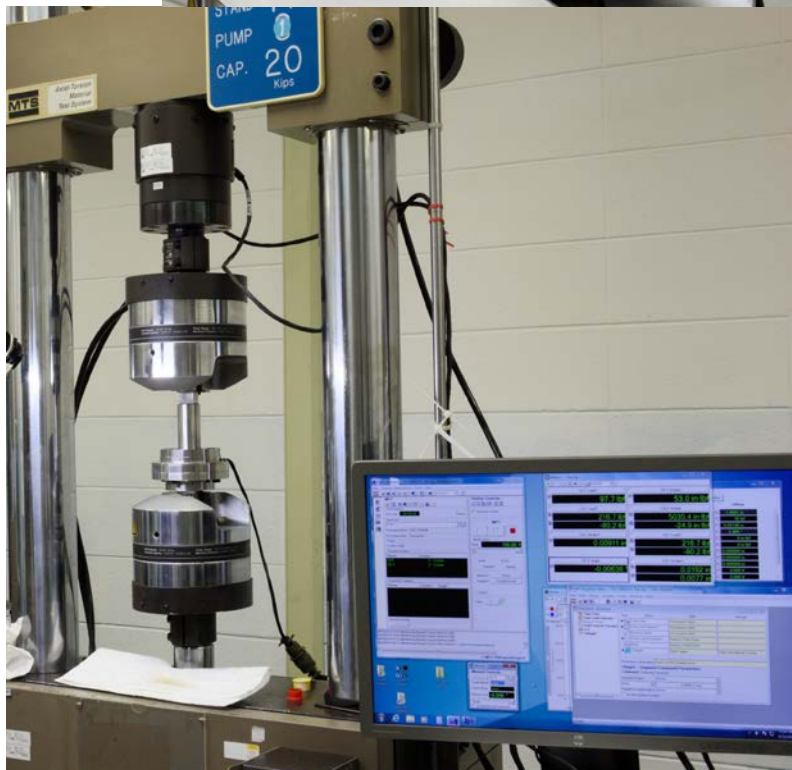
- 17-4PH conventionally machined using mill/lathe operations, no EDM
- 8 strain gages placed at various locations with two locations per specimen having replicates





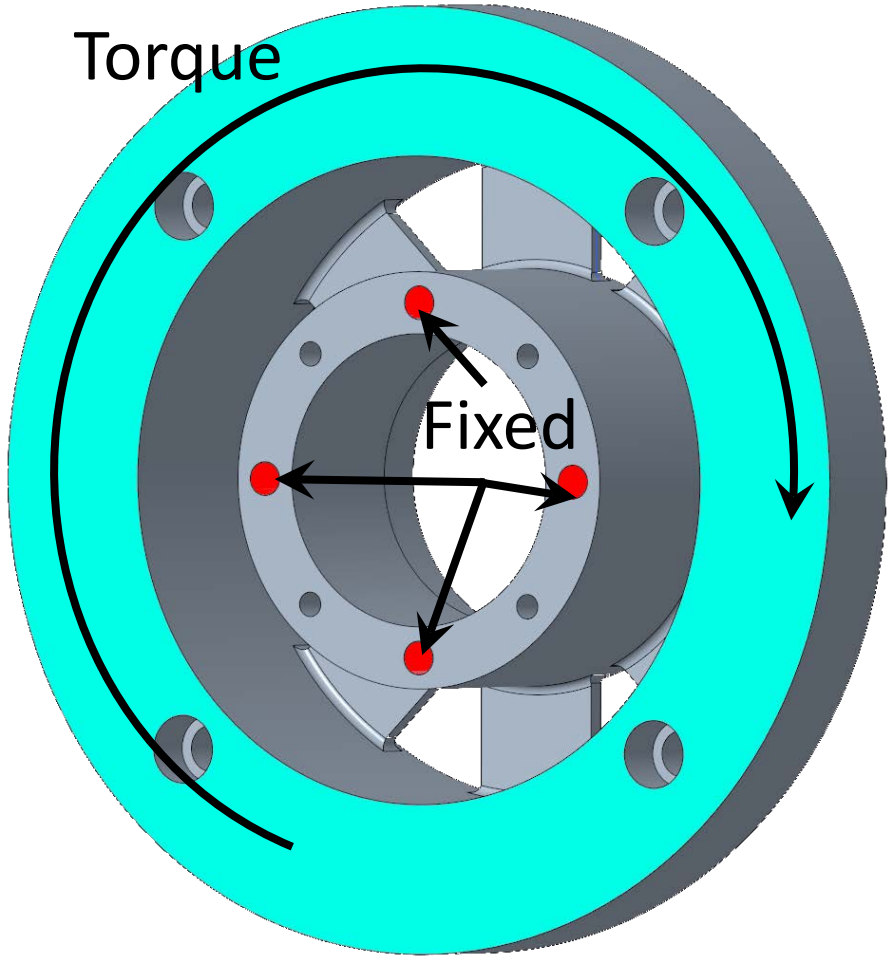
Test Method

- MTS Tension-Torsion machine was used to apply loads to specimens
- Torque was only applied to the specimen, small tension load to engage grippers
- Maximum torque was scaled from balance design loads based on difference in material properties

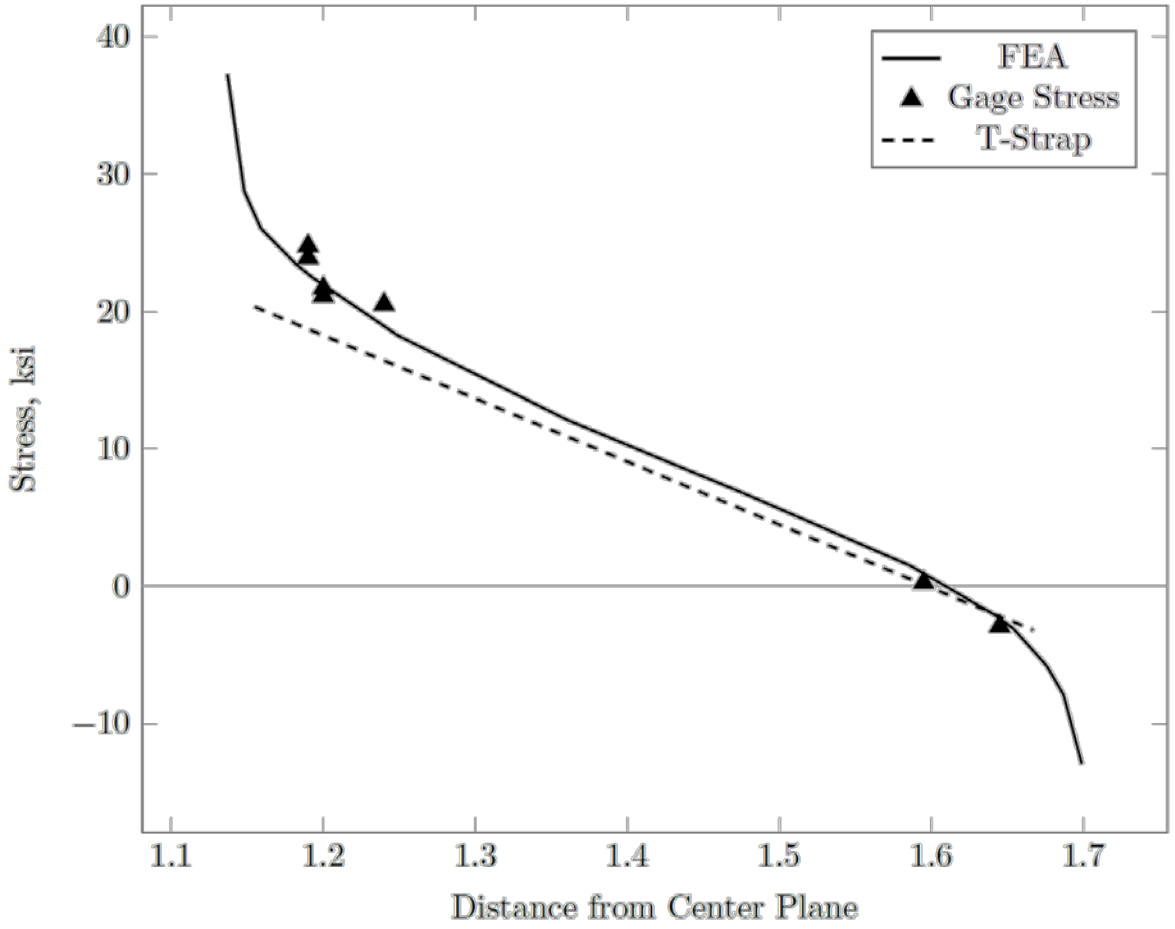


Specimen FEA Model

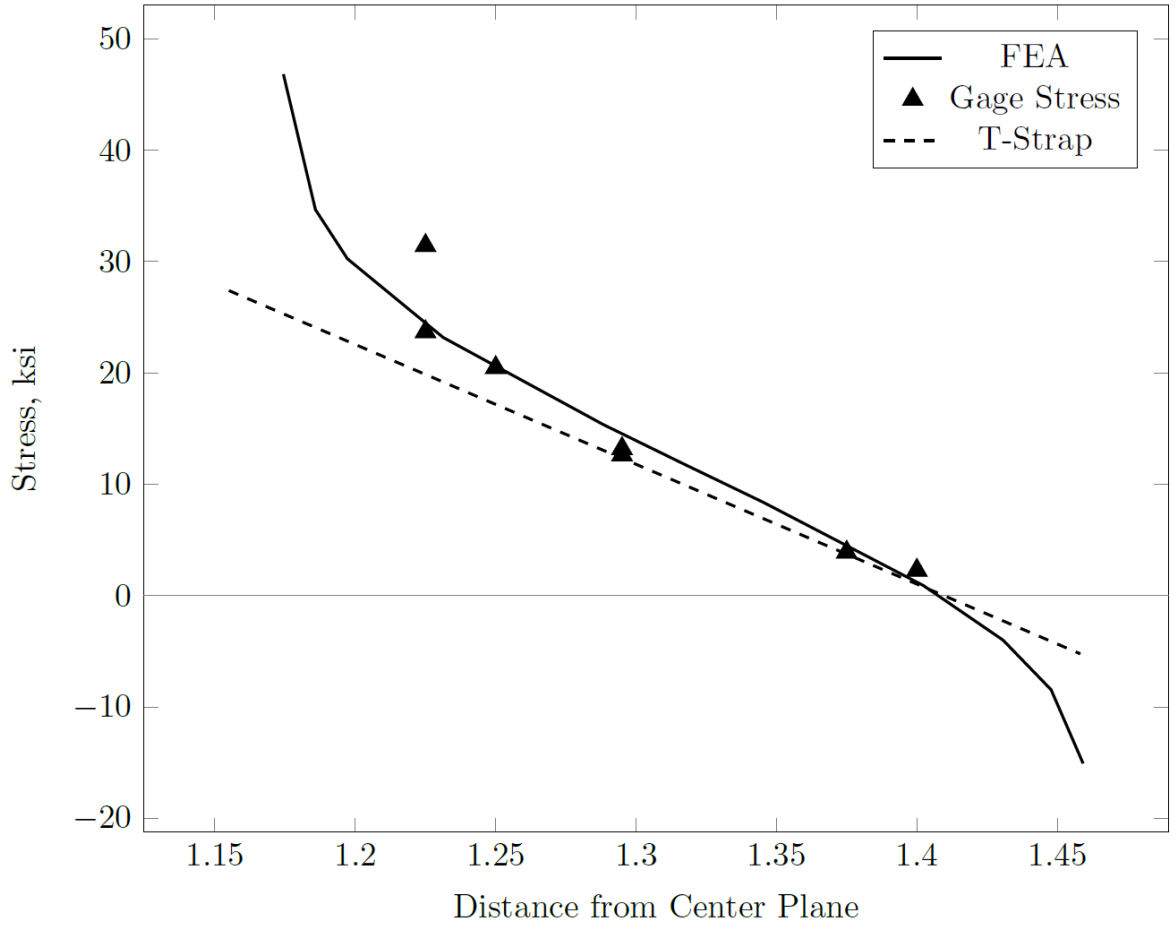
- FEA models of each specimen were simulated to 5% convergence
- Measures taken along side of beam for detailed stress profile
- Constraints applied to outer and inner diameter



Model Validation Results

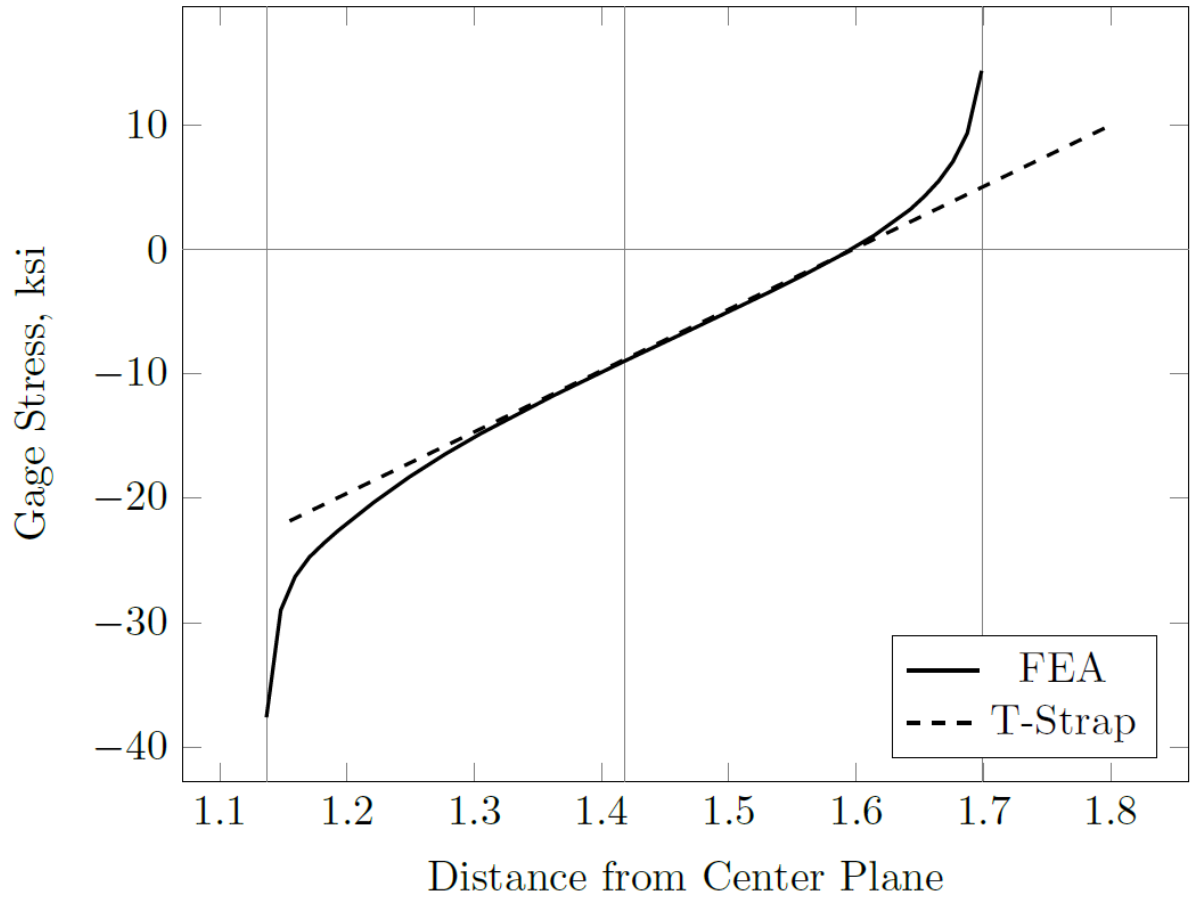


GRC-419R



GRC-517R

Model fit on GRC-419R



Conclusion

- Deformation of the outer diameter of the balance leads to combination of single and double bending in spokes.
- Modification to the established T-strap method enabled analytical estimations of torque stresses on measurement beams
- Validation study and fabricated balance showed agreement between analytical, FEA, and actual gage stresses