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Title: Neutron Diffraction Study of Residual Stress in a Multi-Pass Gas Tungsten Arc Weld

Author(s): Sisneros, Thomas A.
Brown, Donald W.
Clausen, Bjorn
Milewski, John
Steinzig, Michael L.

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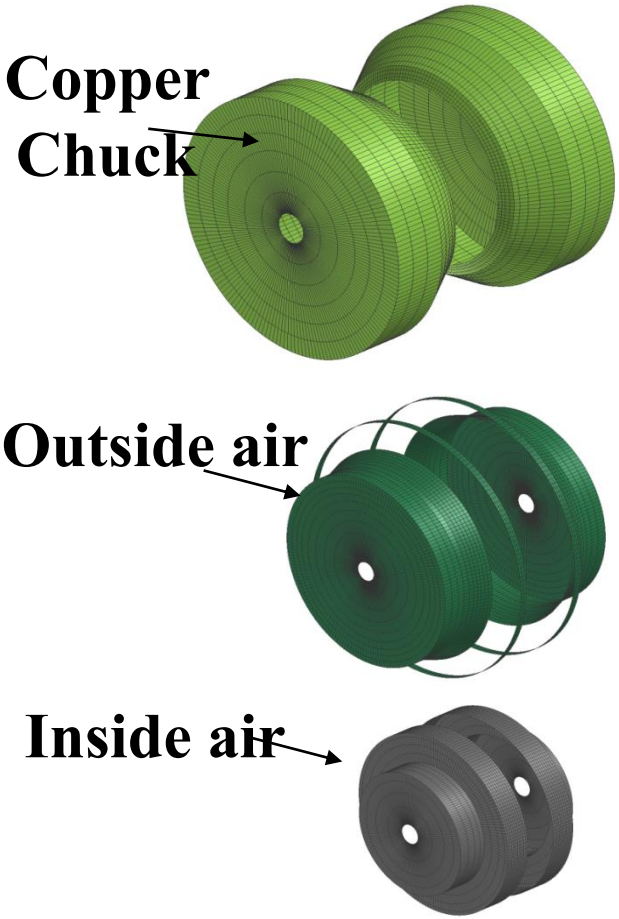
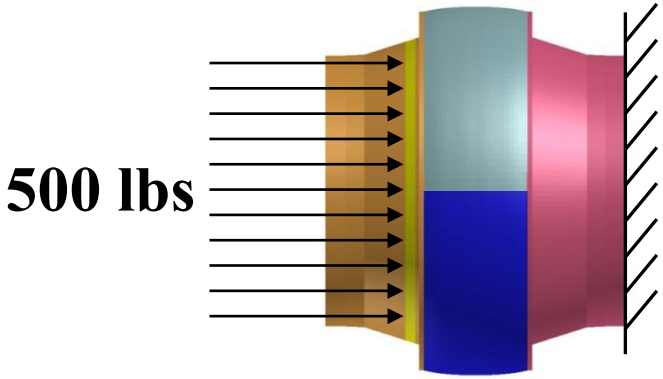
NEUTRON DIFFRACTION STUDY OF RESIDUAL STRESS IN A MULTI-PASS GAS TUNGSTEN ARC WELD

Thomas Sisneros, MST-8
Donald Brown, MST-8
Bjørn Clausen, LANSCE-LC
John Milewski, MST-6
Mike Steinzig, W-2

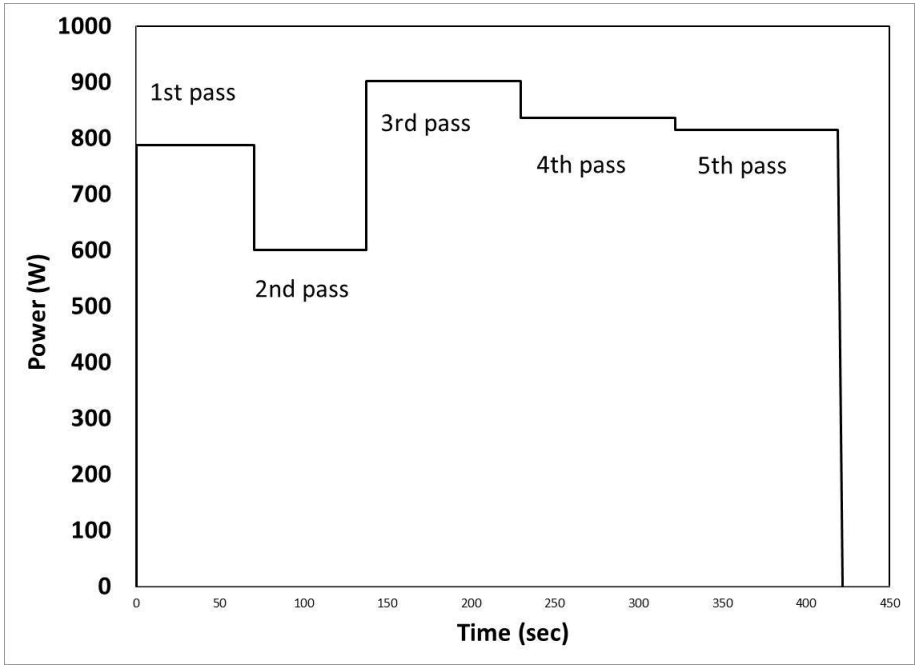
Sample Preparation





Clamping Boundary Conditions

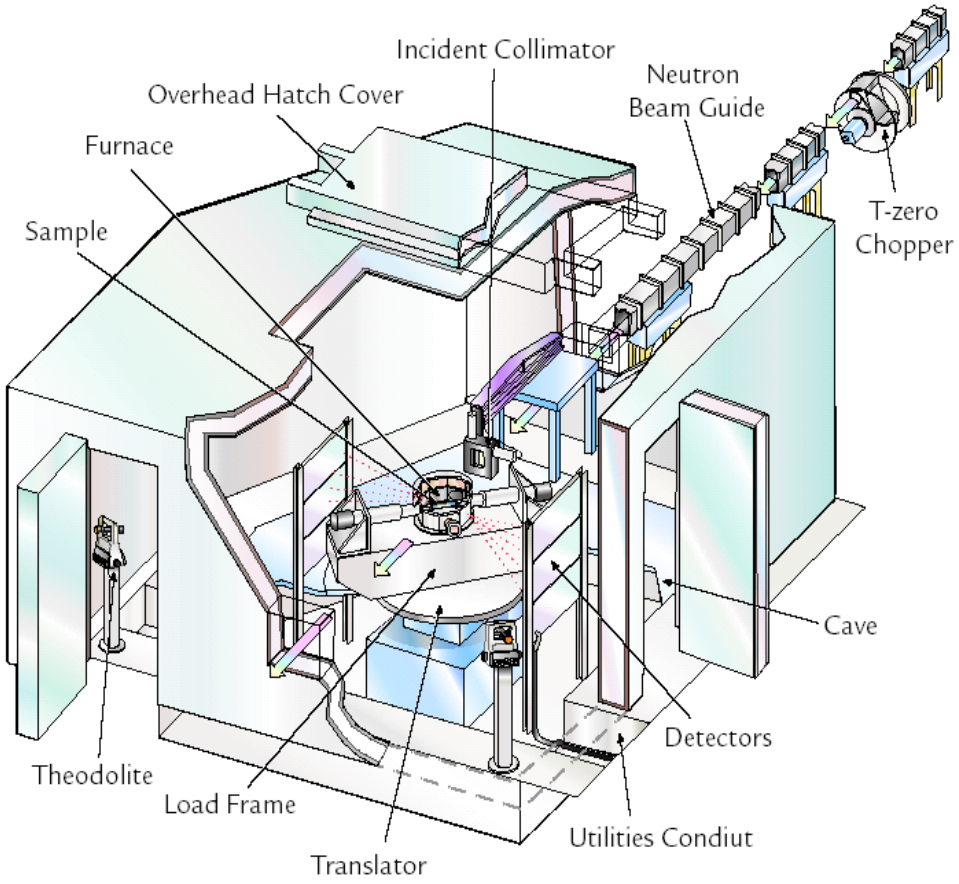
Welding Parameters



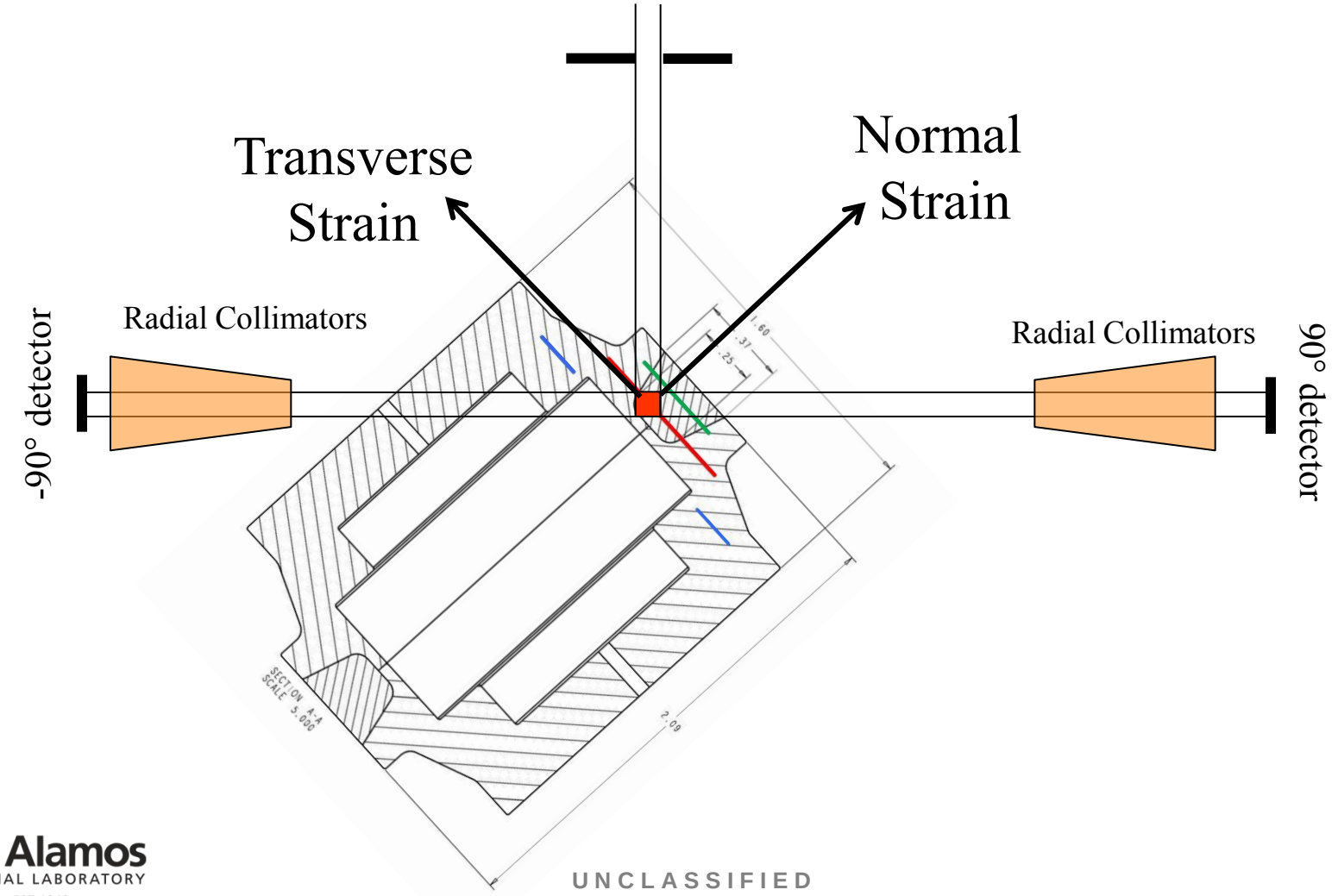
Pass	Power (W)	Speed (mm/sec)	Energy/ Unit Length (J/mm)	Efficiency	QF (W)	QR (W)	AF (mm)	AR (mm)	B (mm)	C (mm)	TC Inside (°C)
1	787	1.79	472	0.60	2.00	1.00	1.33	2.7	1.5	0.20	390
2	601	2.10	487	0.81	2.00	1.00	1.33	2.7	1.5	0.20	390
3	902	1.68	767	0.85	2.00	1.00	1.33	2.7	1.5	0.20	390
4	836	1.81	711	0.85	2.00	1.00	2.00	2.0	1.5	0.20	380
5	814	1.86	692	0.85	2.00	1.00	2.00	2.0	2.0	0.10	360

Residual stress measurements completed using SMARTS

- **S**pectrometer for
  MAterials
  Research at
  Temperature and
  Stress
- Spatially resolved measurements
  - Residual strains in components
- *In situ* measurements
  - Strains as a function of stress, temperature, environment, …
- Instrument Scientists:
  - Donald W. Brown
  - Bjørn Clausen
  - Thomas A. Sisneros

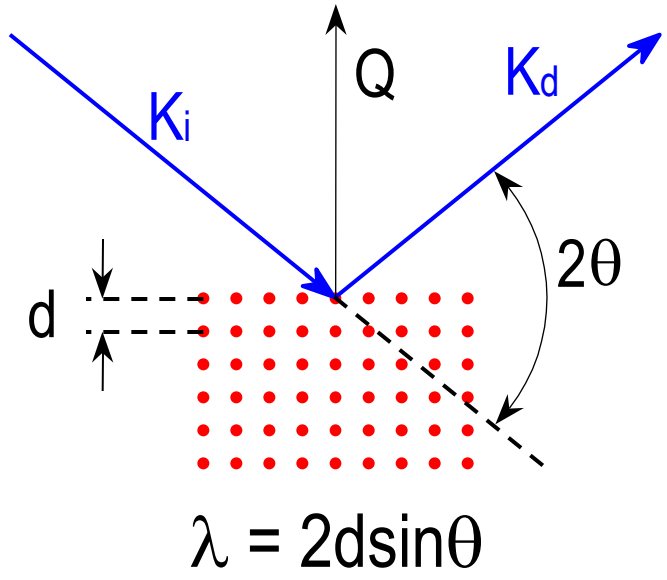


Instrument Geometry Allows 2 Strain Components to be Determined Simultaneously



Information Obtained from Diffraction Measurements

- Bragg's law relates the wavelength, the lattice spacing and the scattering angle



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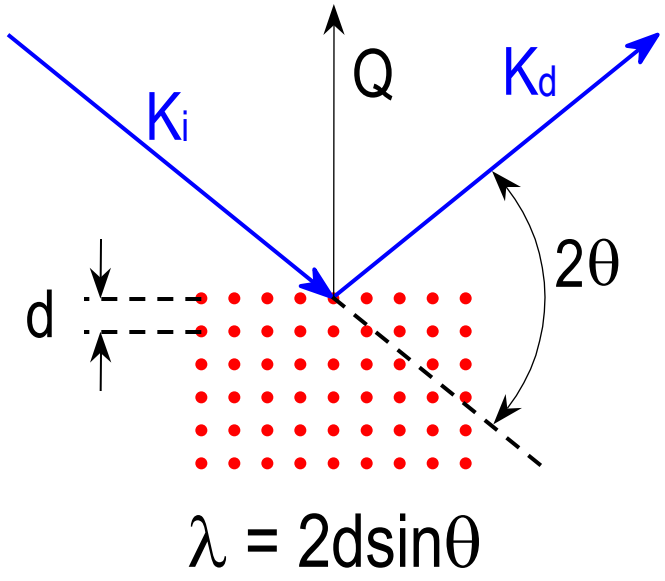

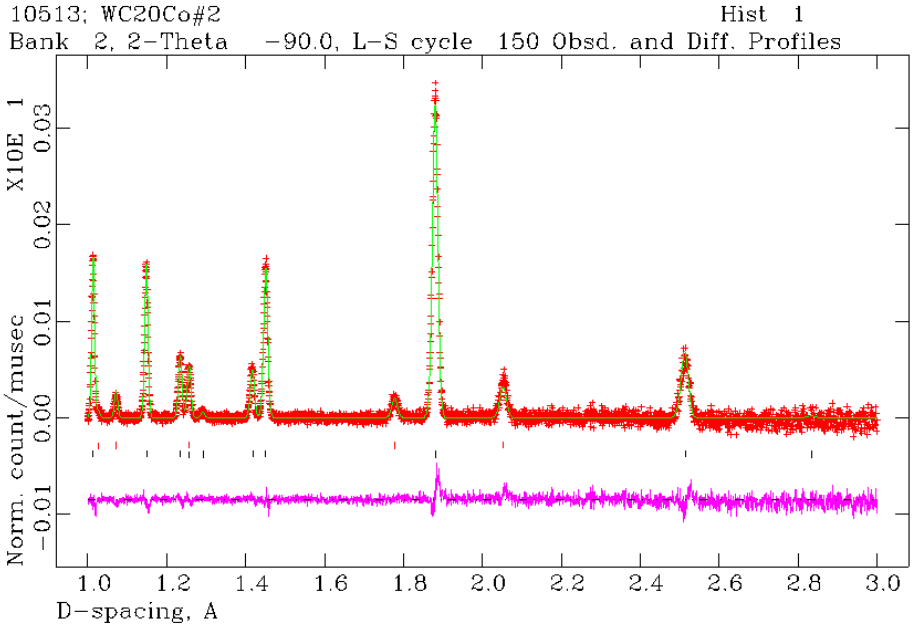

$$\varepsilon_{hkl}^{el} = \frac{d_{hkl} - d_{hkl}^{0}}{d_{hkl}^{0}} = \frac{d_{hkl}}{d_{hkl}^{0}} - 1$$

Stresses from Measured Strains

$$\sigma_i = \frac{E}{(1+\nu)(1-2\nu)}\left[(1-\nu)\varepsilon_i + \nu\left(\varepsilon_j + \varepsilon_k\right)\right], \quad i, j, k \in r, h, a$$

- Three normal stress components can be calculated from the three measured normal strain components via Hooke's Law
  - The measured strains have to be representative of the bulk

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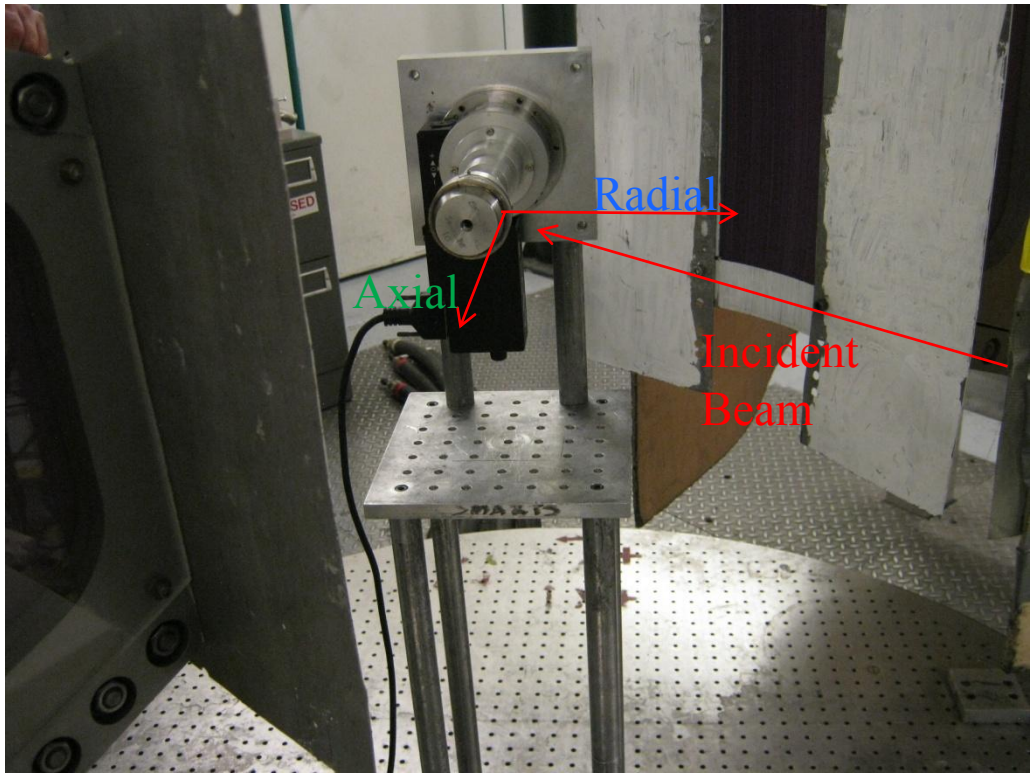
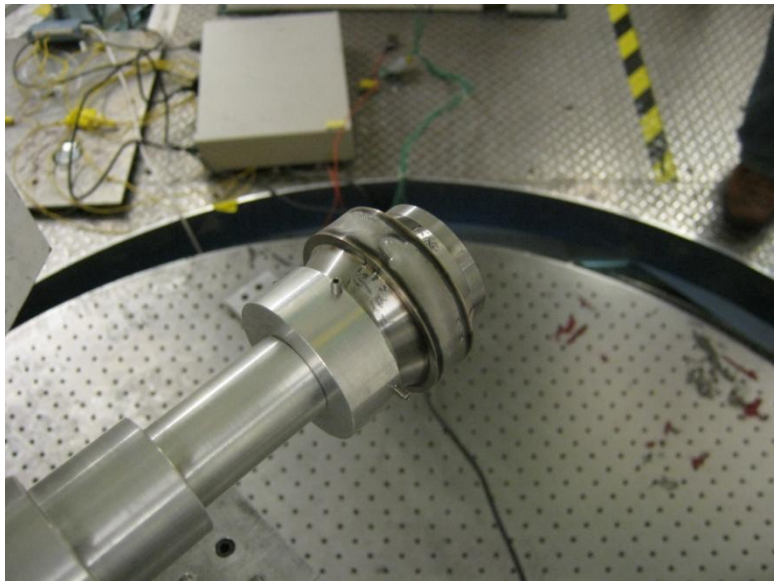
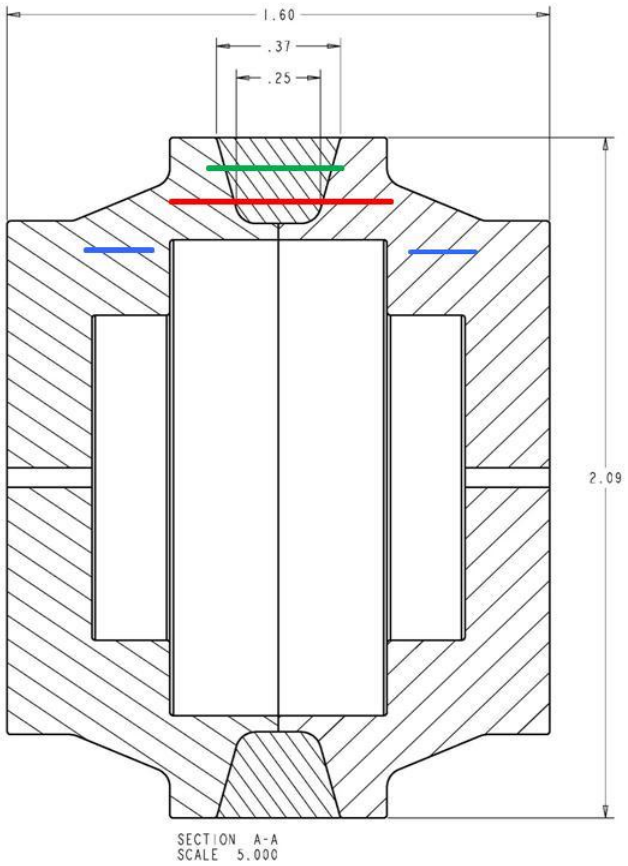
- Three normal stress components can be calculated from the three measured normal strain components via Hooke's Law
  - The measured strains have to be representative of the bulk
- Since we cannot measure shear strains, there is no information about shear stresses
  - If the three measured strain components are not along the principal strain directions, there will be unknown shear stresses
  - If six or more normal strain components are measured one can determine the full strain and stress tensors

Measuring Axial and Radial Strain Components



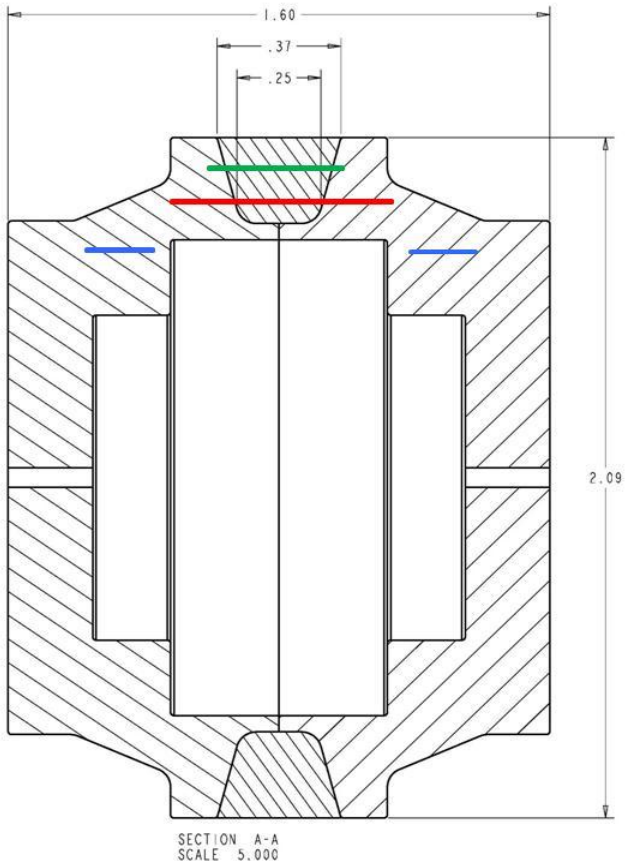


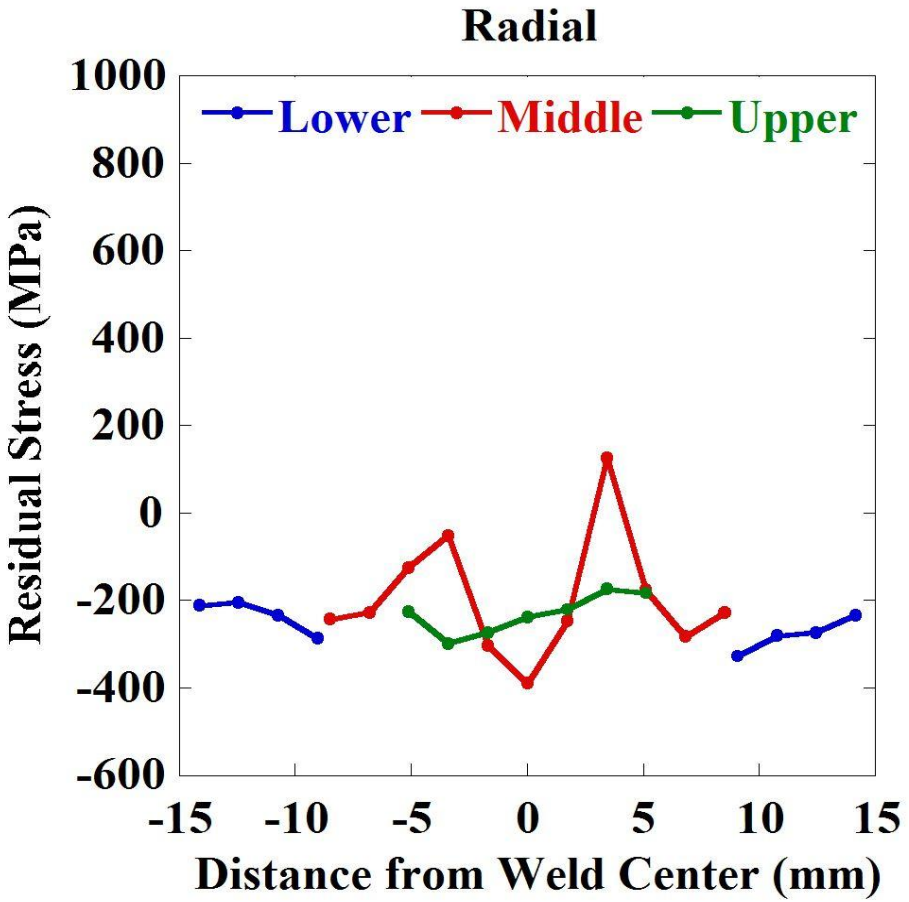
Transverse Measurements



- Scans transverse to the weld were completed at three different depths: Upper, Middle and Lower positions using a 2mm x 2mm x 2mm gauge volume
- Scan transverse to weld, 90º from the Weld stop in the direction of weld travel

Neutron Diffraction Shows Strong Tensile Hoop Stress at Weld Middle line





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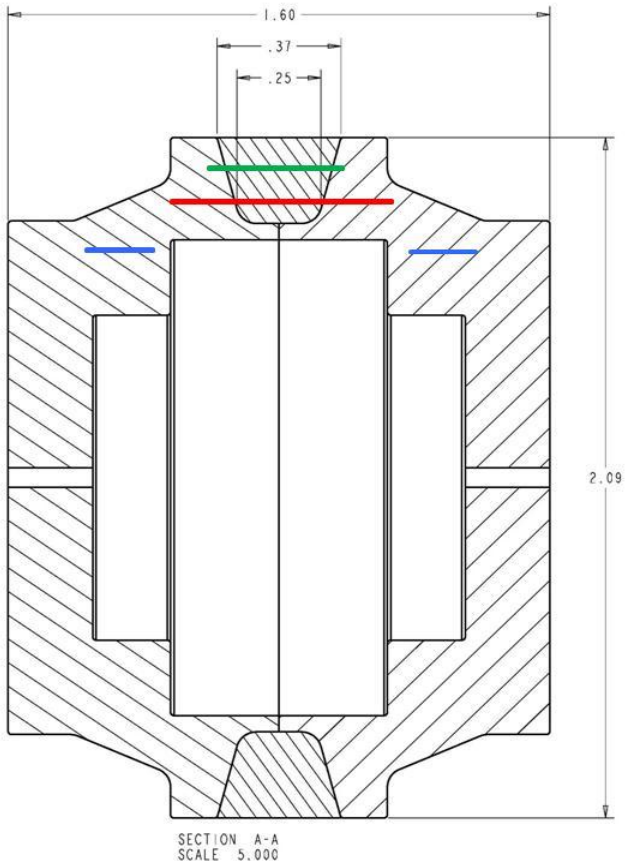

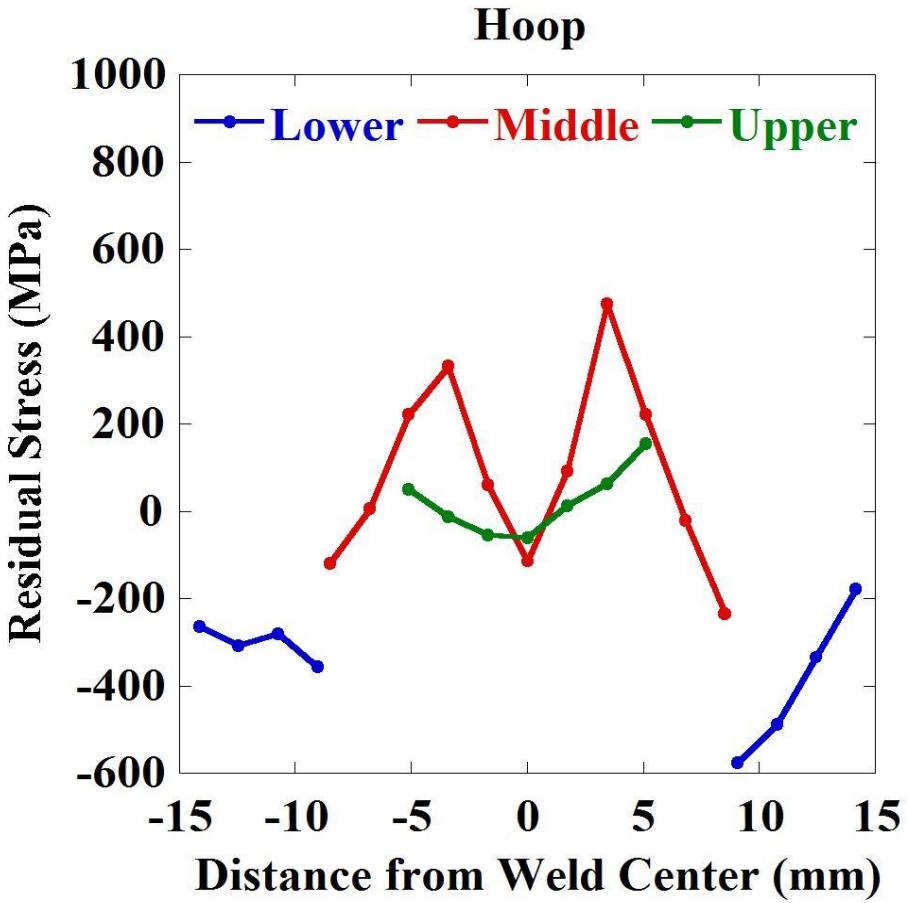

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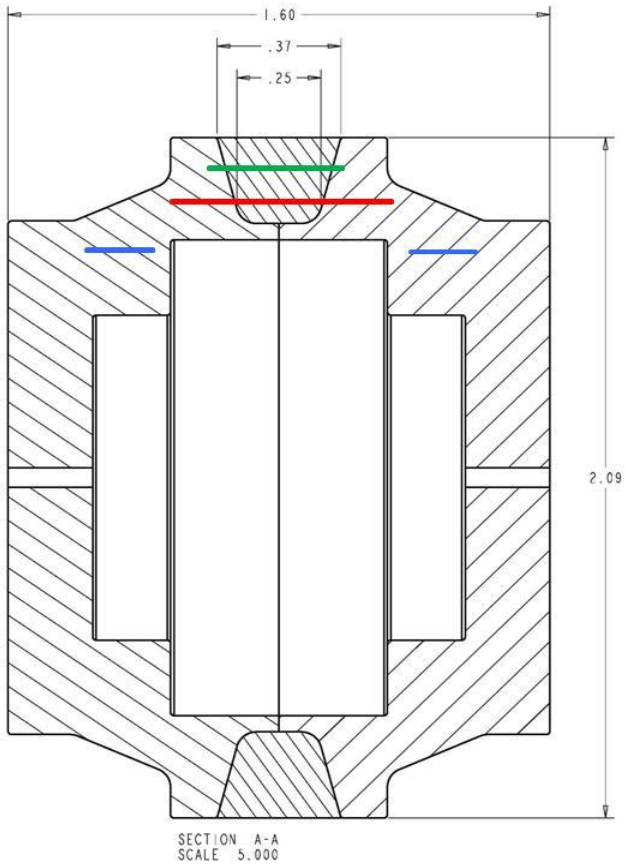
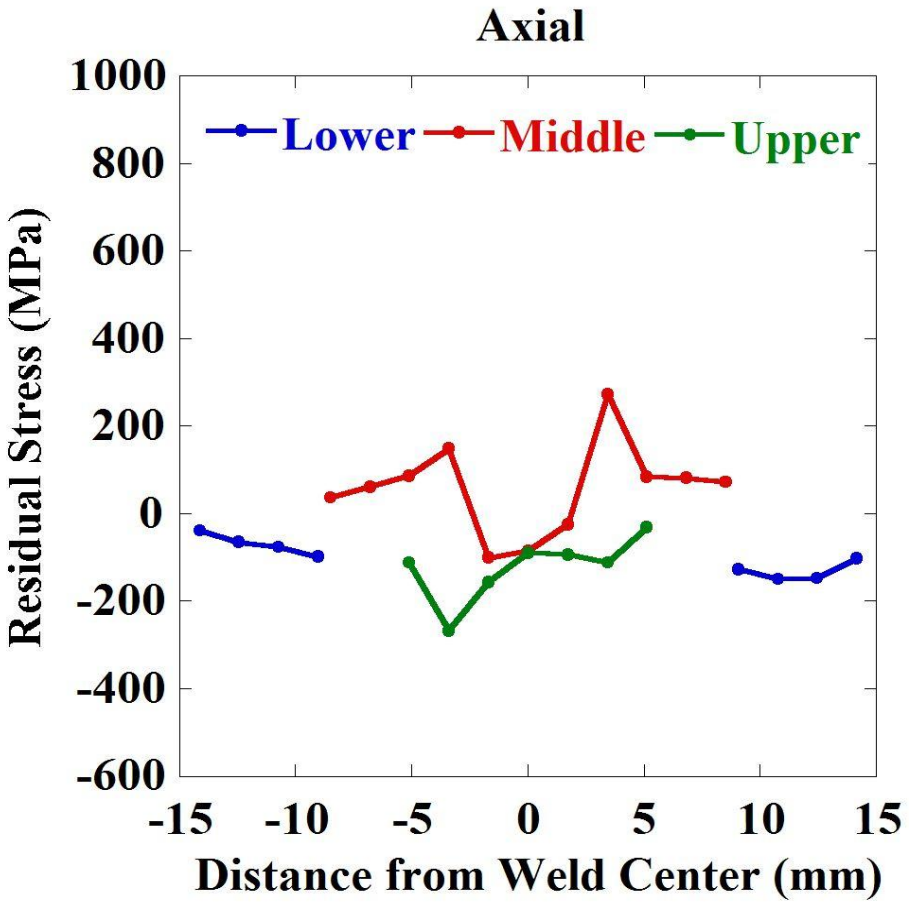
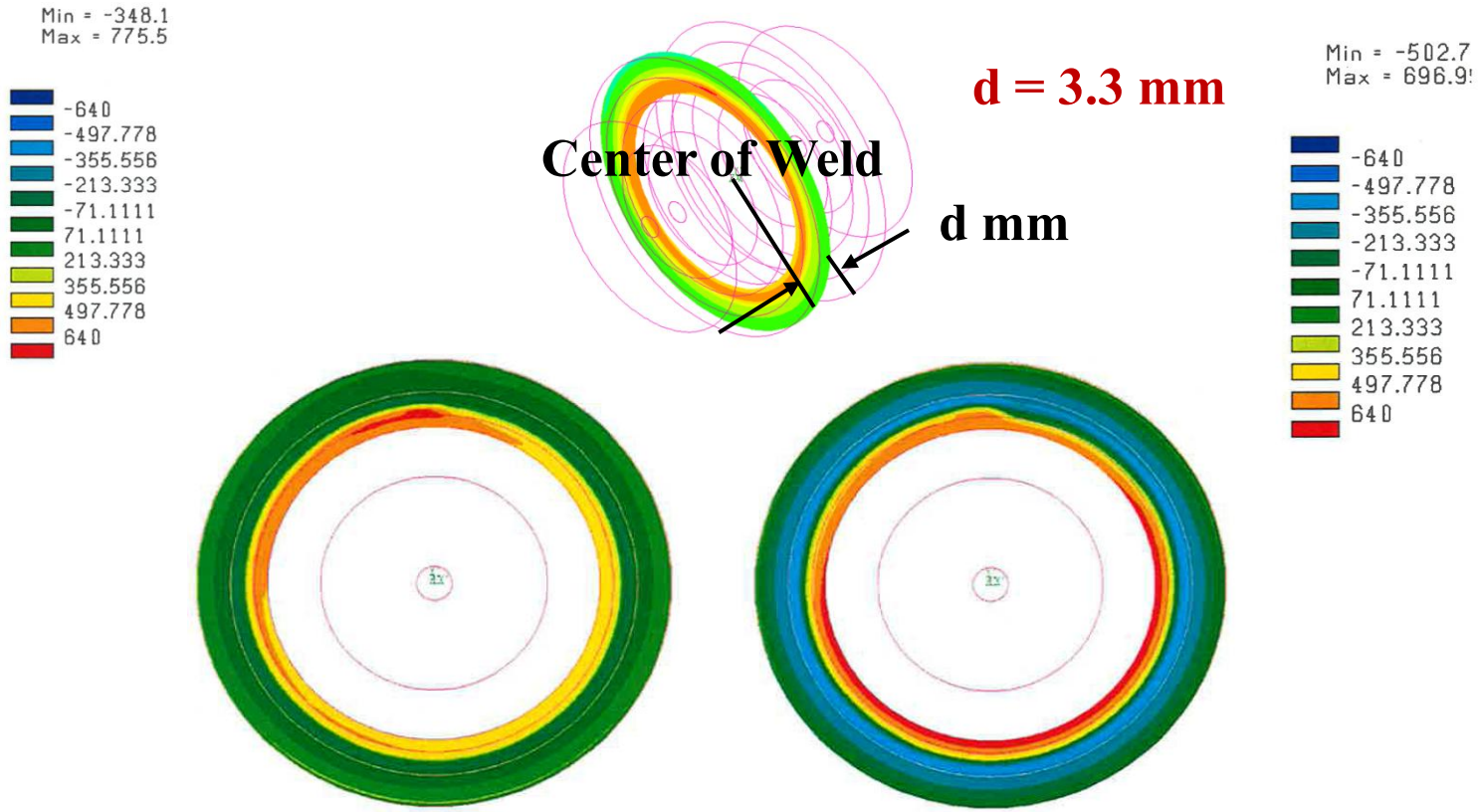




Circumferential Hoop and Axial Stress

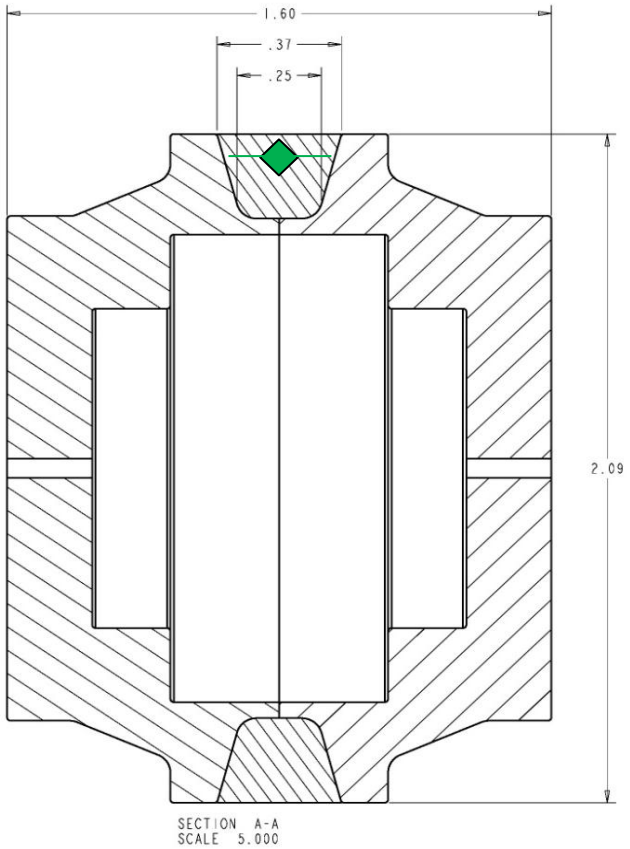


Hoop stress

Axial stress

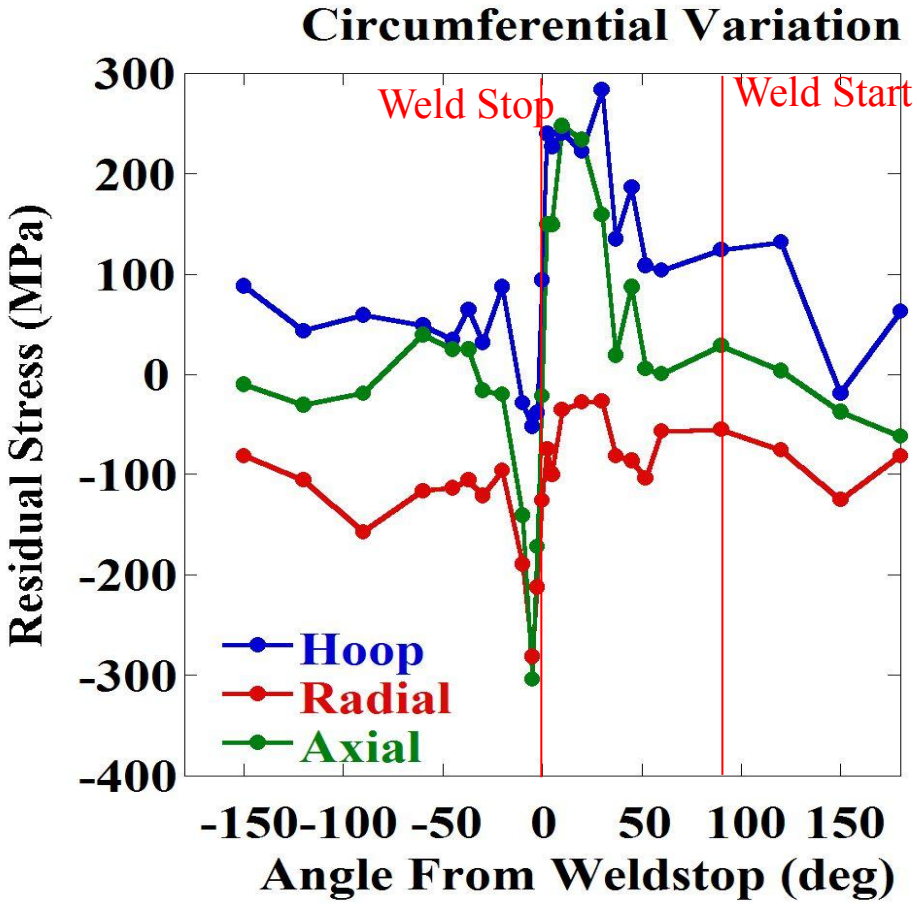
UNCLASSIFIED

Circumferential Measurements



- Circumferential Scans were completed at the upper position using a 2mm x 2mm x 2mm gauge volume
- Vessel 11: Weld start located 95º WRT to weld stop

Neutron Diffraction Shows Circumferential Variation of Stress



Conclusions

- Residual stress neutron diffraction measurements were performed on model specimens welded using Gas Tungsten Arc
- Chemical Strains are very important and should be accounted for.