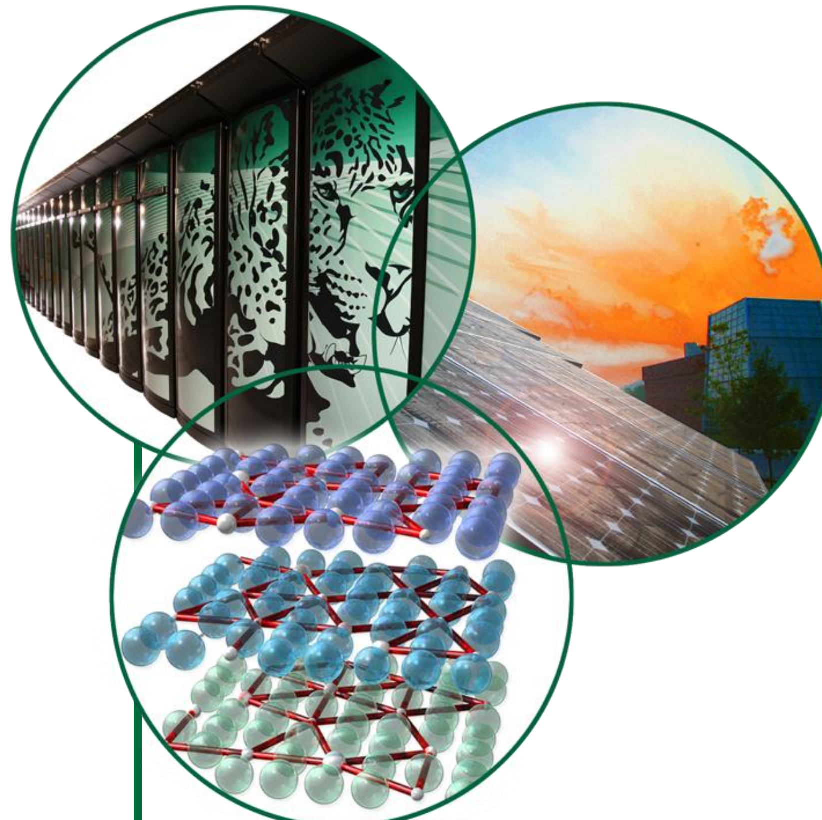
Weld Property Measurement in High-Pressure Hydrogen

Project Status Update October 2012



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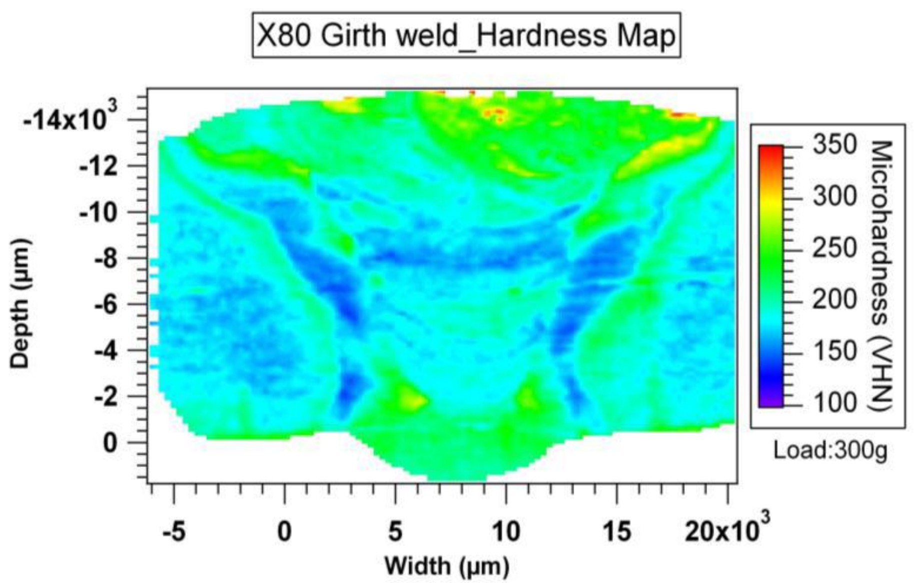
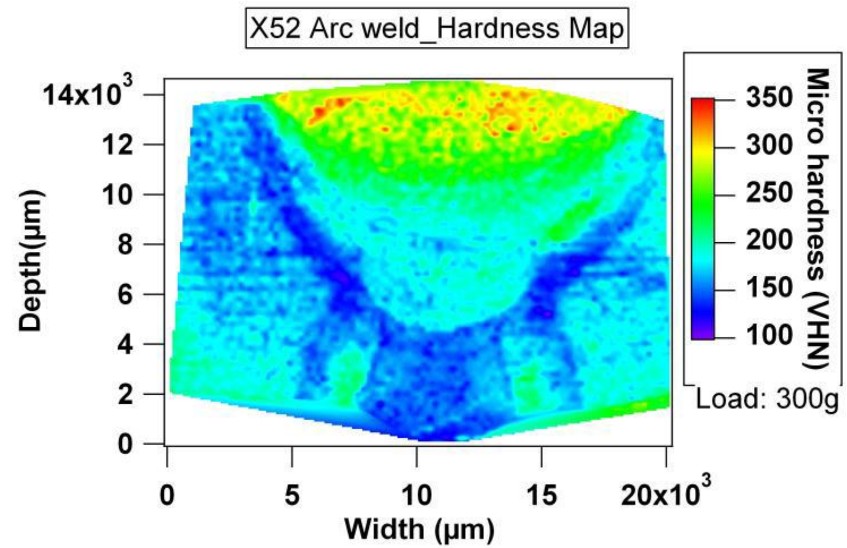
Overview of ongoing activities

- OSU:
  - Microstructure characterization of weld metal, heat-affected zone (HAZ) and base metal of X-52 arc welding, X-52 friction stir welding, and X-80 arc welding
- ORNL:
  - Fracture toughness testing with spiral notch torsion test (SNTT)
  - Cyclic fatigue (S-N curve) testing

X-80 weld versus X-52 weld





Berg Steel Pipe

Material	C	Si	Mn	Ni	Cr	Mo	V	Cu	Ti
X-80 Girth weld (wt%)	0.05	0.24	1.70	0.125	0.1	0.2	0.007	0.28	0.13

- **Welding condition: Voltage: 19-34V, Current: 120-500A, DCEP (spray mode)**
- **Weld pass: 6 or 7**

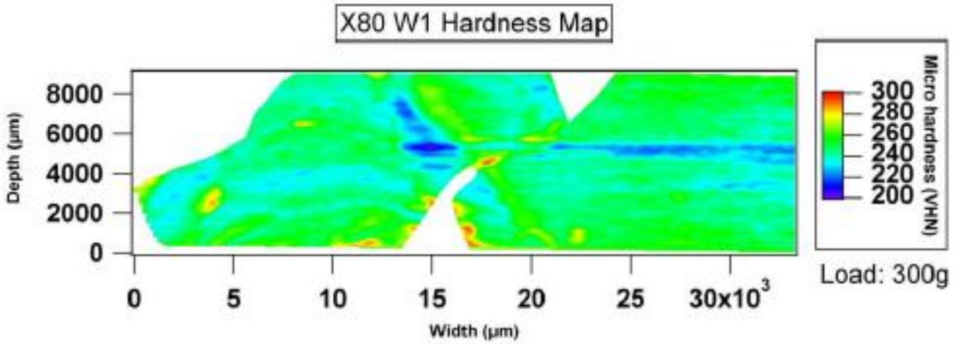
Evraz Oregon Steel Mills

Material	C	Si	Mn	Ni	Cr	Mo	V	Cu	Ti
X-52 arc weld (wt%)	0.06	0.12	0.87	0.02	0.03	0	0.002	0.03	0

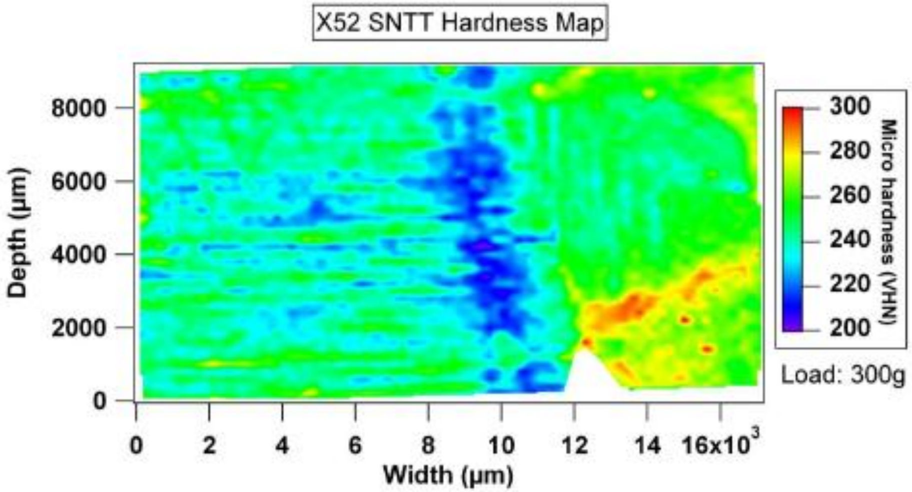
- **Welding condition: Voltage: 24-26V, Current: 200-300A, DCEP**
- **Weld pass: 5**

Hardness maps for X-80 and X-52 SNTT

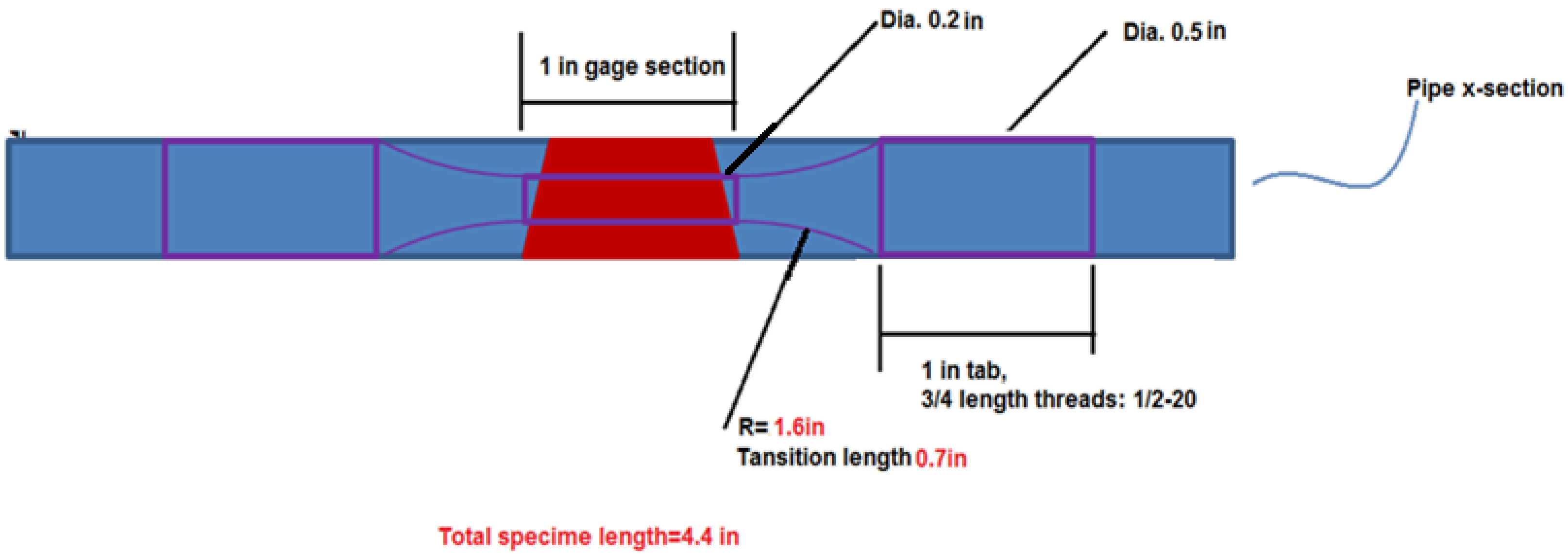
X80 SNTT W1_Macrostructure



X52 SNTT Macrostructure



Cyclic fatigue (S-N curve) testing

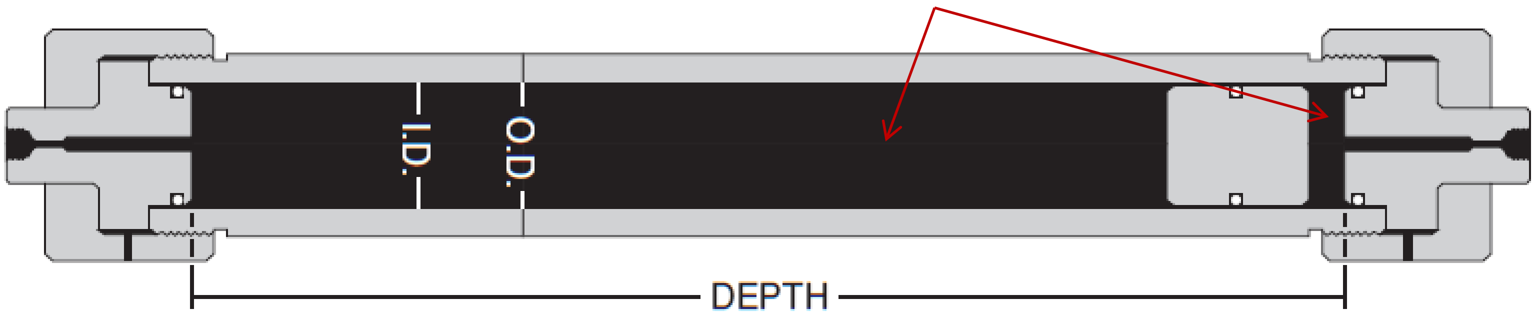


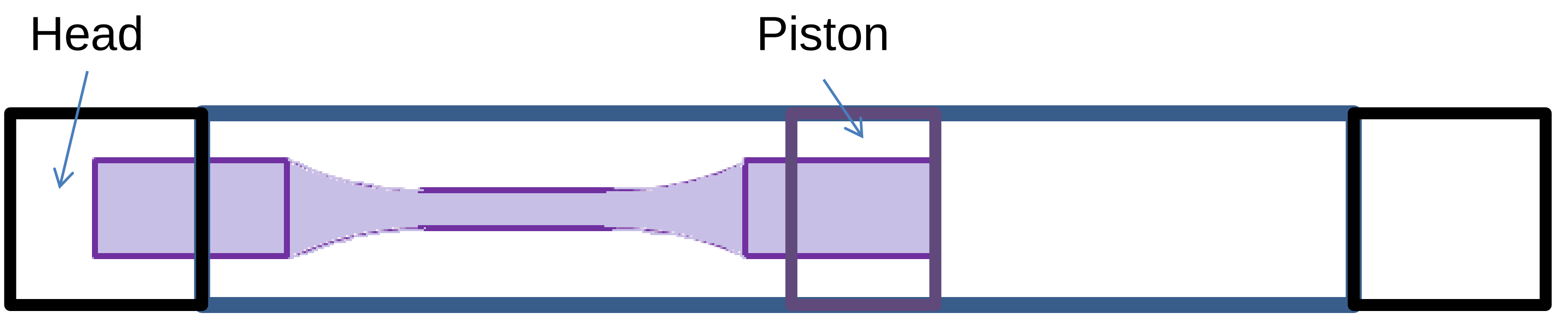
Assume a weld region of 1 in.
Total specimen length ~4.4in with a gage section =1 inch

Ref.: ASTM E 466 – 07, "Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials"

Fatigue loading "actuator"

Tensile (or compressive) loading produced by the H_2 pressure difference between the two chambers separated by a piston

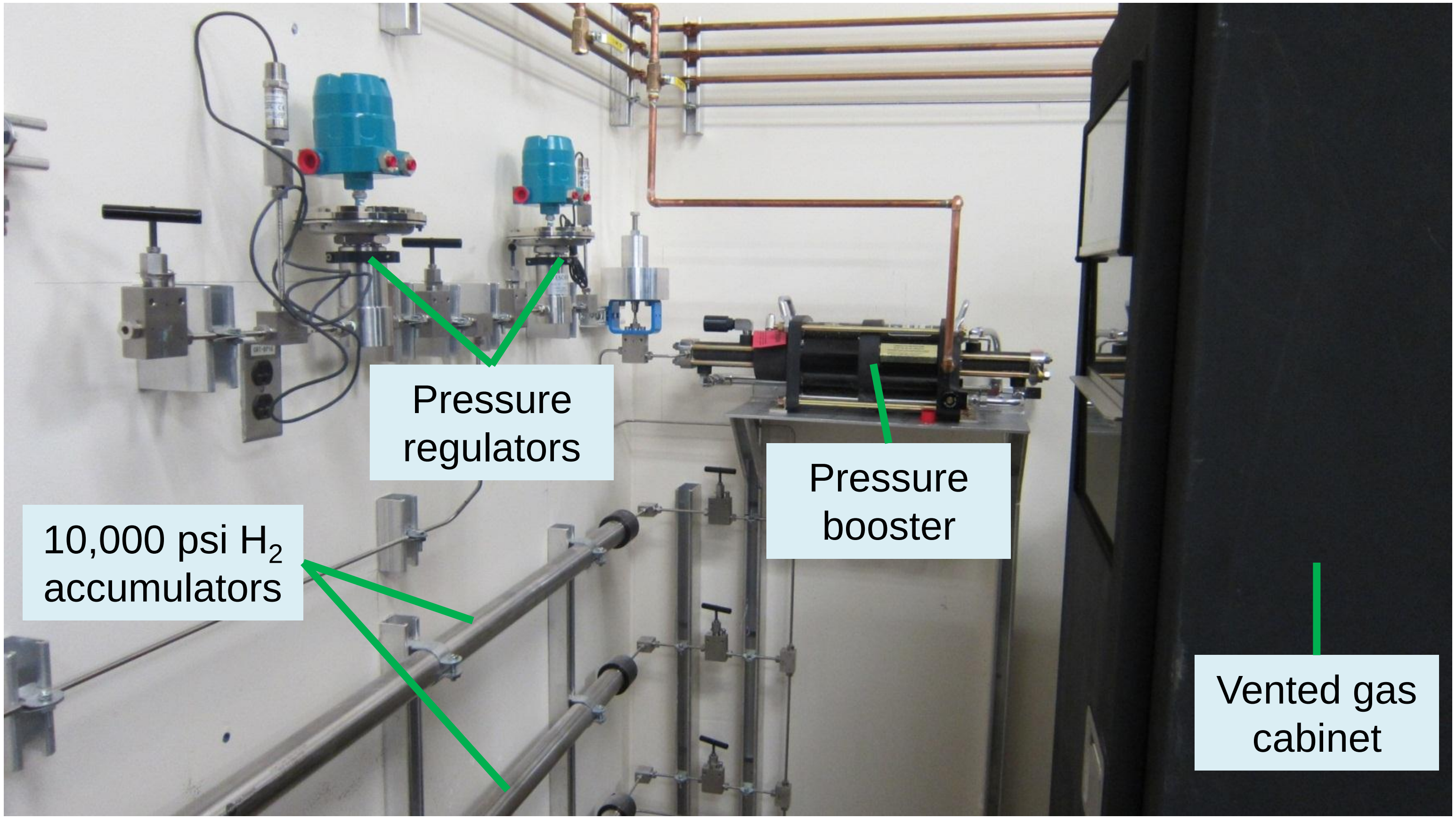




- Suitable for low-frequency high-cycle fatigue testing
- Cost-effective due to the "low-cost" load frame

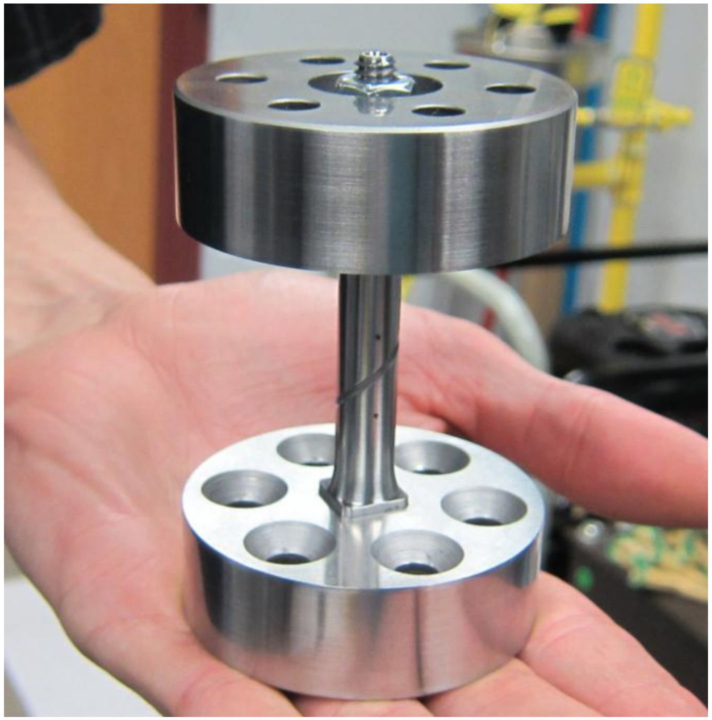
Ref.: ORNL Patent Application, "An Apparatus and Method for Fatigue Testing of a Material Specimen in a High-Pressure Fluid Environment," 2006.

High-pressure testing framework in support of hydrogen testing

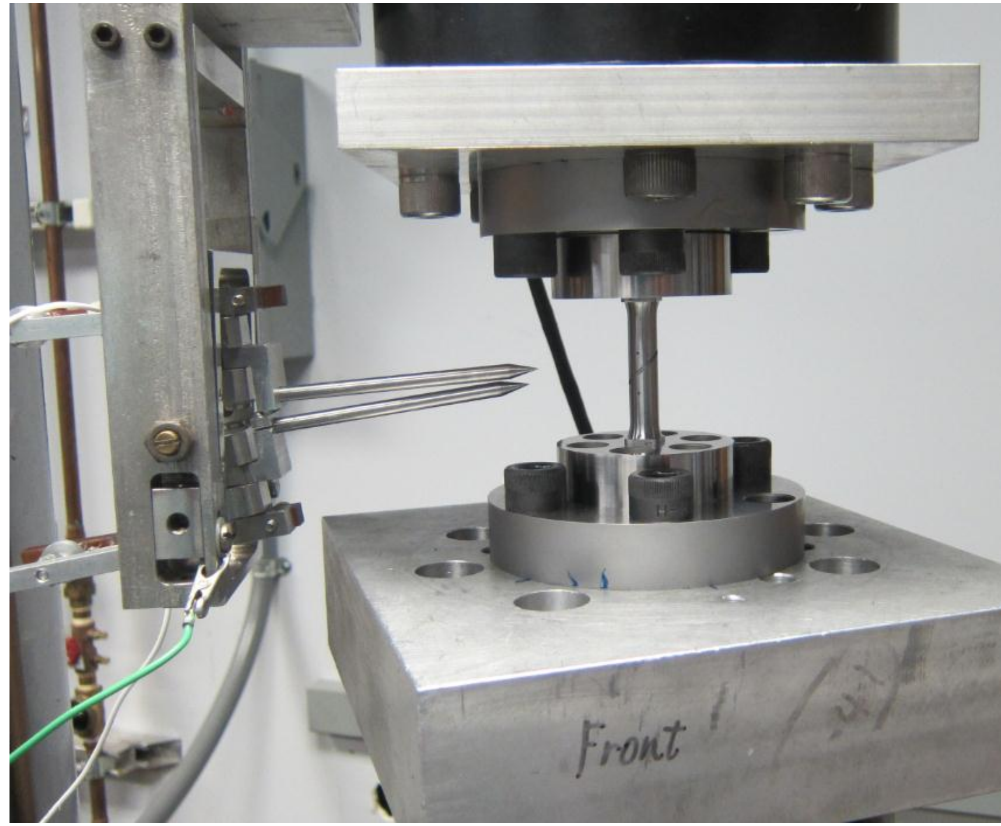


Leveraging the prior work at ORNL sponsored by U.S. Department of Energy

SNTT for measuring fracture toughness of pipeline steels and welds



Grips for loading the torsion sample with a spiral notch



Torsion testing with a bi-axial extensometer to measure rotational displacement

Reference for Spiral notch torsion testing (SNTT):

J Wang and K. C. Liu, Journal of Nuclear Materials 381 (2008) 177-184.

Further development needed to address technical challenges in SNTT

- Previous experience with SNTT is mainly for low to median tough materials (i.e., K_{IC} lower than about 75 MPa m^0.5).
- For high toughness pipeline steels, the method needs to be extended into elastic-plastic region.
- For testing, we are working on getting acoustic emission equipment to work properly and the biaxial extensometer sensor part.

Table 1
SNTT K_{IC} evaluation

Materials	K_{IC} (MPa$\sqrt{m}$)	
	SNTT	Method conventional[a]
A302B steel	55.8	55.0 CT
7475-T7351 Al	51.3	51.0 Vendor/CT
Mullite ceramic	2.21	2.20 3P
MA956 Inconel	68	Not available
Graphite	1.0	1.0 Vendor/CT

[a] In TL orientation and at room temperature.

Previous SNTT testing results

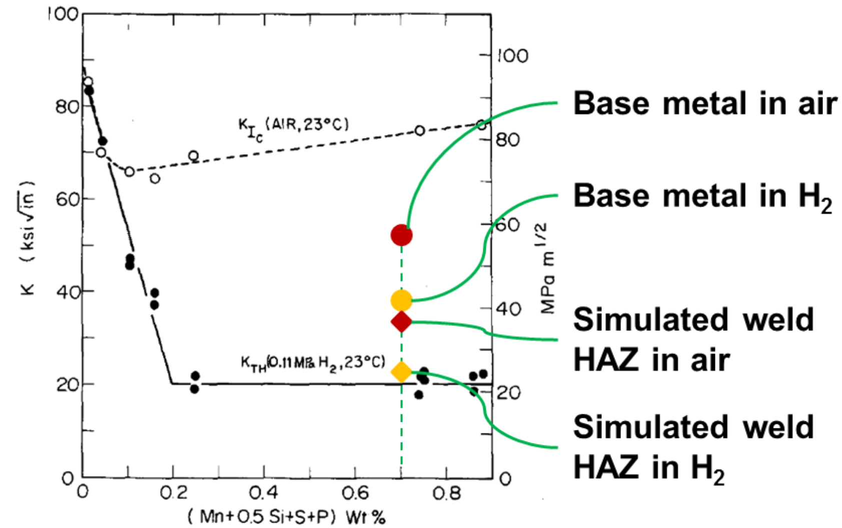


Figure adapted from N. Bandyopadhyay, et al., 1983.

4340 steel

Work planned for upcoming months

- To complete the cyclic fatigue testing system
  – Hydrogen charging hardware and fatigue loading cell
  – LabVIEW software program for testing and data recording
- To continue SNTT development for elastic-plastic testing
- To continue development of improved filler metal for hydrogen embrittlement