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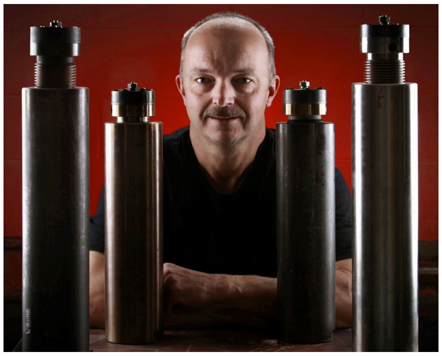

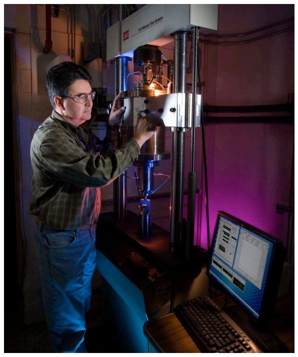

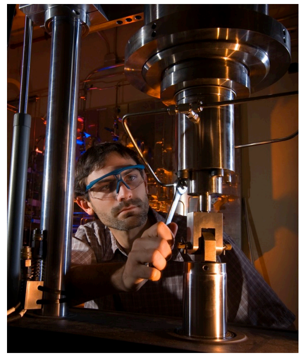

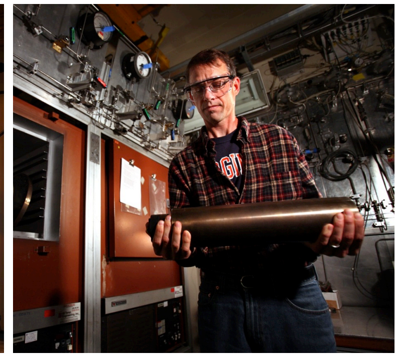

Fatigue Crack Initiation in Hydrogen-Precharged Austenitic Stainless Steel

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Kevin A. Nibur, Hy-Performance Materials Testing LLC, Bend OR

Abstract

- Fatigue is a concern for high-pressure gaseous hydrogen fueling infrastructure
- Effects of gaseous hydrogen on fatigue crack initiation are relatively unknown; additionally test methods for accelerated testing in hydrogen environments are needed
- Fatigue life is measured for 21Cr-6Ni-9Mn austenitic stainless steel after thermal precharging with hydrogen
- Tension-tension fatigue of circumferentially notched specimens is used to simulate component structures
- Direct current potential difference (DCPD) is used to probe crack initiation

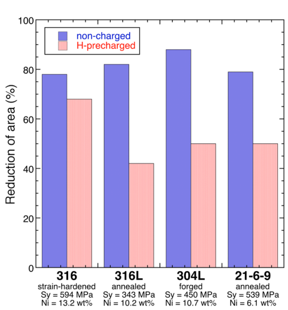
Materials and Tensile properties

Composition of 21Cr-6Ni-9Mn austenitic stainless steel used in this study

Fe	Cr	Ni	Mn	Si	C	N	S	P
Bal	20.45	6.15	9.55	0.52	0.033	0.265	0.0013	0.018

Tensile properties of 21Cr-6Ni-9Mn; from 14mm diameter bar

Condition	Yield strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Reduction of Area (%)	Notched Strength (MPa)
Non-charged	539	881	61	79	1438
H-precharged	669	957	55	50	1495



Hydrogen-precharging reduces the tensile ductility of austenitic stainless steels.

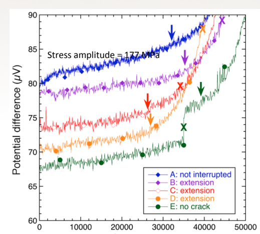
- Reduction of area in hydrogen-precharged 21Cr-6Ni-9Mn is consistent with reports for other austenitic stainless steels.

Specimens are thermally precharged in gaseous hydrogen at pressure of 138 MPa and temperature of 300˚C for 25 days; this results in hydrogen concentration of approximately 220 wt ppm for 21Cr-6Ni-9Mn

References: (1) San Marchi et al. *Intern J Hydrogen Energy* **33** (2007) 889; (2) Switzner et al. 2012 International Hydrogen Conference (Moran WY).

Fatigue Properties

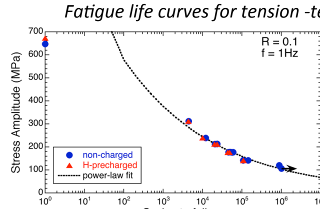
- Circumferentially notched specimens with stress concentration factor Kt ~ 6 (specimen consistent with notched tensile specimen from ASTM G142)
- Stress ratio R = 0.1 and frequency f = 1 Hz

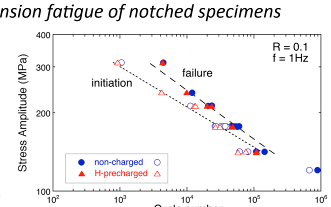


Measured potential difference as a function of cycle number for interrupted tests

- Test interrupted (at '**X**'); specimen heat tinted to mark extent of fatigue crack extension; test continued to failure
- Tests B, C and D show crack extension on heat-tinted fracture surface
- Test E shows no crack extension
- Crack initiation is identified by vertical arrows for each test

Fatigue life curves for tension -tension fatigue of notched specimens





- Monotonic tests are plotted with stress amplitude of 45% of notched tensile strength
- Curve fit to data for non-charged condition

- For maximum stress greater than net-section yield, initiation is 20-25% of cycle life
- For maximum stress less than yield, initiation is about 55-65% of cycle life
- Lines for trend only

Conclusions

- Hydrogen precharging of 21Cr-6Ni-9Mn reduces tensile ductility by about 40%, consistent with reductions reported for other austenitic stainless steels
- The fatigue-life curve (Wöhler curve) is not significantly affect by hydrogen precharging for notched specimens in tension-tension fatigue
- Crack initiation can be detected with DCPD monitoring, which shows initiation to represent from 20 to 70% of the fatigue life for this testing configuration
- Hydrogen precharging does not affect crack initiation

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