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Fatigue behavior of austenitic steels with hydrogen

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Motivation:

- Fatigue due to pressure cycling is a likely failure mode for pressure components exposed to hydrogen
  - Relatively little data comparing H-degradation of various fatigue-life test methods or separating contributions to total fatigue-life
  - Need to understand hydrogen and fatigue compatibility of new alloys for hydrogen storage

Goals:

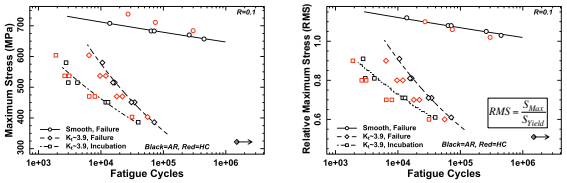
- Compare hydrogen degradation of load-controlled tension-tension fatigue-life with and without a local stress concentrator.
  - ***How does stress-environment affect H-degradation?***
- Compare the relative fatigue performance of austenitic stainless steels in the presence of H.
  - ***Can low Ni steels perform as well as 316L?***

Hydrogen and stress concentration effects on fatigue-life of 316L stainless steel (1)

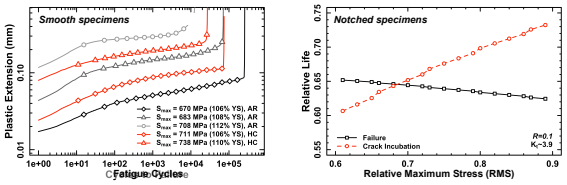
- Thermally H-charged (HC) specimens tested in air
- Measured crack incubation with potential-drop in notched and plastic ratcheting in smooth specimens

Yield strength (YS) ↑ with HC
Stress-life typically ∝ to YS

Condition	YS (MPa)	UTS (MPa)	RA (pct.)
AR	635	731	74
HC	670	774	62



Smooth: ↑ in HC fatigue-life consistent with YS ↑
Notched: ↓ in fatigue-life and incubation-life



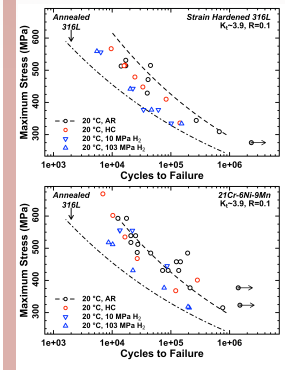
Increased plastic extension in HC condition at equal RMS
H-enhanced plastic flow

Incubation-life decreased by H
Enhanced plasticity; reduced crack incubation and fatigue-life

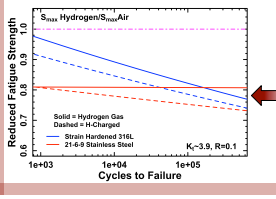
Increase in YS not seen in external H_2, artifact of H-charging
may be due to solute drag or slip localization in deforming volume
Accounting for YS increase suggests increased plasticity due to H
consistent with increased dislocation source activity due to H
↓ fatigue-life possibly due to ↓ tolerance to strain accumulation

Directly compare tension-tension fatigue of strain-hardened 316L (2) and 21Cr-6Ni-9Mn

- Fatigue-life tests performed in air (AR) , air after hydrogen charging (HC), and in 10 MPa and 103 MPa gaseous hydrogen



316L (2): *Decrease in fatigue-life in presence of hydrogen*
21Cr-6Ni-9Mn: *Fatigue-life depends on hydrogen environment*
Accounting for YS ↑ with HC aligns 103 MPa and HC data



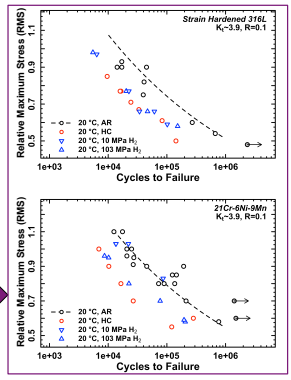
Both 316L (2) and 21Cr-6Ni-9Mn show ↓ in fatigue strength in H at longest measured life
Enhanced plasticity encourages low stress fatigue damage

Composition

Alloy ID	Cr	Ni	Mn	Mo	C	N
316L (2)	17.6	12.0	1.15	2.05	0.020	0.04
21-6-9	20.5	6.15	9.55	NR	0.033	0.265

Tensile properties

Alloy ID	S_Y (MPa)	S_U (MPa)	RA (pct.)
316L (2) - AR	573	731	77
316L (2) - HC	*648*	*793*	*60*
21Cr-6Ni-9Mn - AR	539	881	79
21Cr-6Ni-9Mn - HC	*669*	*957*	*50*



- Hydrogen decreases the fatigue performance of austenitic stainless steels
- Hydrogen appears to change plastic strain evolution, encouraging crack formation
- ***YS ↑ in HC steels obscures load-controlled results***

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