

Proposed test method to establish hydrogen compatibility of materials for fuel cell vehicles

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Motivation: establish materials compatibility for high-pressure hydrogen service in context of hydrogen fuel cell electric vehicles

Status:

- **Test methodology for materials compatibility evaluation has been submitted for review**
- **Awaiting feedback from stakeholders**
 - **Please provide feedback by August 20, including technical basis for concerns**
 - **Technical discussion being organized to coincide with next SAE Fuel Cell Safety Task Force**

Goals of testing

- **Slow strain rate tensile (SSRT) test**
 - ***Screening test for strength and ductility***
 - **Demonstrate that specified minimum strength properties are satisfied**
 - **Demonstrate sufficient ductility**
- **Fatigue life test (two options)**
 - ***Screening test for fatigue life***
 - **Smooth: demonstrate that fatigue limit is not changed in hydrogen**
 - **Notched: demonstrate that fatigue life is conservative by greater than 9 times (in life)**

Open questions and lack of consensus

1. **Modify test pressure for SSRT**
 2. **Eliminate verification of gas quality**
 3. **Eliminate allowance for welds, or prescribed additional details**
 4. **Eliminate notched fatigue life test option**
 5. **Add stress corrosion cracking of aluminum in humid gas (HG-SCC)**
- ***Awaiting feedback from stakeholders on other issues and concerns***
 - **Technical discussion being organized to coincide with next SAE Fuel Cell Safety Task Force Meeting**
 - **Please provide feedback by August 20**

Summary

- **Relatively simple screening test metrics drafted for**
 1. **Strength and ductility (SSRT)**
 2. **Fatigue life (two options: smooth and notched)**
- **Awaiting additional feedback from stakeholders**
 - **Feedback by August 20 to prepare for SME discussion on September 10 in Troy MI (participation is encouraged)**
- **Known concerns and issues with proposed testing requirements**
 1. **Test pressure: increase pressure for SSRT – minor**
 2. **Verification of test gas quality – critical**
 3. **Allowance for welds – relevant and addressable**
 4. **Fatigue life test options – open**
 - **Technical basis for both methods (notched and smooth)**
 5. **Stress corrosion cracking of aluminum in humid gas (HG-SCC) – open**
 - **Additional research and test method development is needed**

Backup slides

Summary of requirements to demonstrate hydrogen compatibility

	Slow strain rate tensile (SSRT)	Fatigue Life
Test conditions	<ul style="list-style-type: none"> • H2 pressure ≥ 1.5 NWP • Temperature: varies • Displacement rate $\leq 5 \times 10^{-5} \text{ s}^{-1}$ 	<ul style="list-style-type: none"> • H2 pressure ≥ 1.25 NWP • Temperature: varies • Net-section stress $\geq 1/3S^*$ • Frequency = 1 Hz
Number of tests	3	3
Requirements for each test	<ol style="list-style-type: none"> 1. Yield strength $> S_y$ 2. Tensile strength $> S_u$ 3. Tensile/yield > 1.07 4. Elongation $> 12\%$ 	<ol style="list-style-type: none"> 1. Either (a) or (b) <ol style="list-style-type: none"> a) Smooth: $N > 2 \times 10^5$ b) Notched: $N > 10^5$

Note: S_y and S_u are specified minimum yield and tensile strength respectively;
 S^* is measured tensile strength

Open questions and lack of consensus

1. Test pressure

- ***Increase test pressure of SSRT***
 - **SSRT: 1.5 x NWP (initially 1.25 x NWP)**
 - **Fatigue life: 1.25 x NWP**

- **Increasing pressure may limit the applicability of previously acquired data**
 - **Previous tests have been performed at pressure < 1.5x NWP**

Technical evaluation: minor
SSRT testing at the higher pressure is unlikely to change outcome of testing

Open questions and lack of consensus

2. Verification of gas quality

- **Remove requirement to sample test gas**

- Gas purity is known to affect properties measured in gaseous hydrogen [ref. Somerday]
- Characterization of source gas is not sufficient to establish purity of test gas
 - Purity of test gas depends on purging process prior to each test

Technical evaluation: critical

Confirmation of purity of test gas is essential

- **Proposed solution: periodic evaluation of test gas (not every test), consistent with CSA CHMC1**

Open questions and lack of consensus

3. Allowance for welds

- One contracting party does not allow welds
- Concern also about precise definition of weld and test specimens

- For generic application of tests methods, it is difficult, if not impossible, to be prescriptive

Technical evaluation: relevant and addressable

Welding is used extensively in hydrogen systems and there is no technical basis for disallowing welds

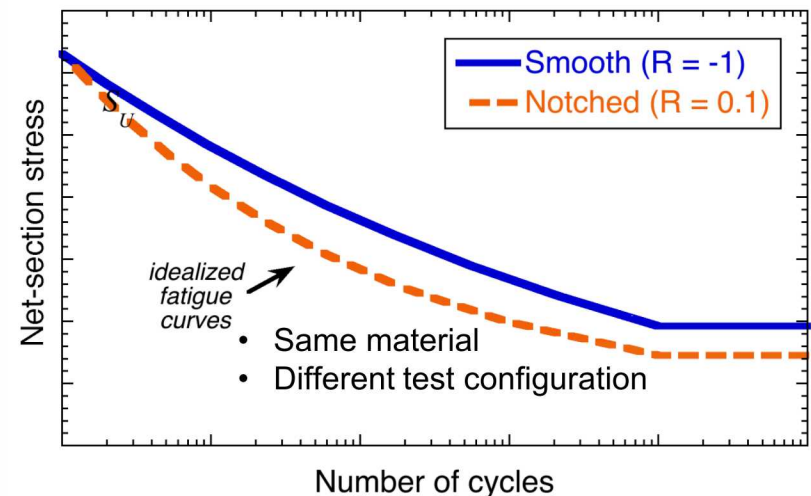
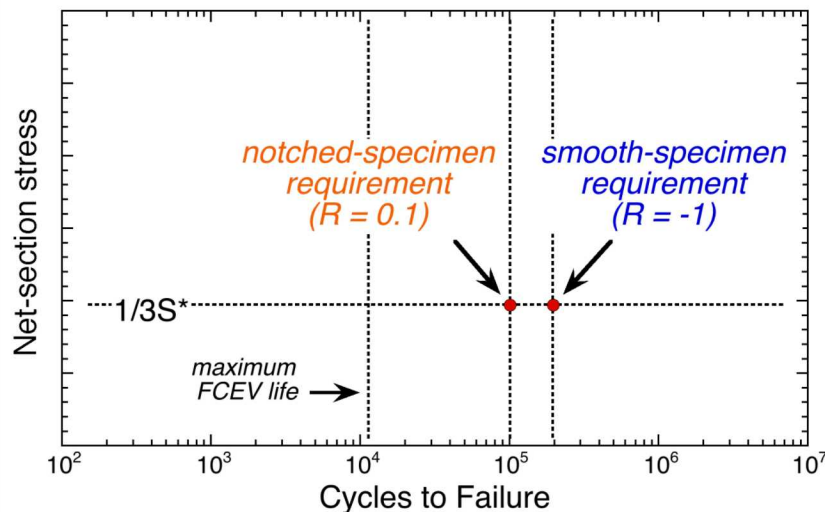
- Potential solutions: (two options)
 1. provide generic performance-based language
 2. Establish prescriptive definition of welding processes and specimen extractions for all weld configurations

Open questions and lack of consensus

4. Fatigue life test options

- One contracting party has expressed dissatisfaction with notched-specimen option

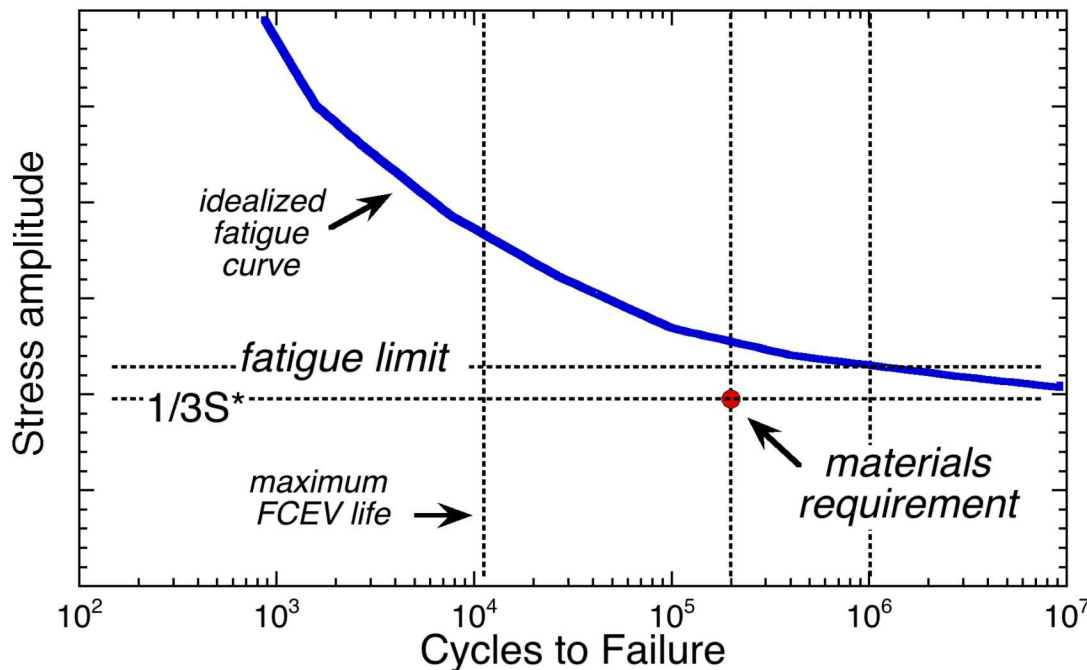
- Smooth and notched specimen tests are both screening tests
- Both methods provide conservative assessment of the fatigue life of the material
- Differing requirements reflect different testing configuration



Open questions and lack of consensus

4. Fatigue life test options

- Smooth-specimen fatigue life test: *establish that hydrogen does not change the fatigue limit*

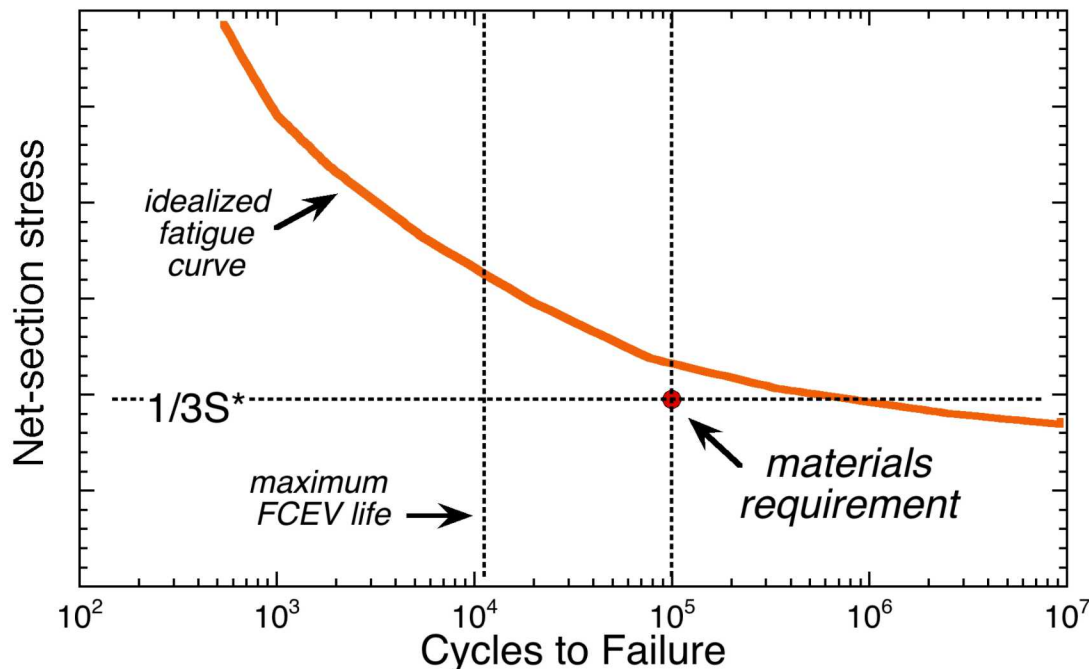


- Maximum FCEV life = 11,000 cycles
- Materials requirement = 200,000 cycles at stress of $1/3S^*$
 - smooth specimen with $R = -1$

Open questions and lack of consensus

4. Fatigue life test options

- Notched-specimen fatigue life test: *establish fatigue life 9x greater than maximum FCEV life*



- Maximum FCEV life = 11,000 cycles
- Materials requirement = 100,000 cycles at stress of $1/3S^*$
 - notched specimen with $R = 0.1$

Open questions and lack of consensus

5. Stress corrosion cracking of aluminum in humid gas (HG-SCC)

- Topic of separate presentation

- High-strength aluminum alloys are known to be sensitive to “wet” hydrogen [*ref. Speidel*]
- Hydrogen vehicle fuel can have as much as 5 ppm H₂O
 - **Open technical question: Is 5 ppm H₂O in H₂ at pressure of 1.5 x NWP sufficient to induce stress corrosion cracking (HG-SCC) in high-strength aluminum alloys?**
 - High-strength aluminum alloys are a desirable option for valves and fittings
 - *More test method development is needed*