A Practical and Effective Test for Rank Ordering Advanced High-Strength Steels Based on Their Sensitivity to Hydrogen Embrittlement

A/SP Delayed Cracking

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The A/SP will deliver to the automotive industry future steel innovations and solutions that meet society's needs for sustainable vehicles

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Project Goals

- To develop a relatively simple, qualification-level test for hydrogen assisted cracking (HAC).
- To avoid the most common concerns with existing tests:
  - Avoid artificial “charging” with hydrogen that may alter the fracture mechanism
  - The test shall be relevant for the evaluation of materials used in body structures/stampings (ie sheet)
  - The test must be able to differentiate performance and be consistent with actual field experience

Project Goals

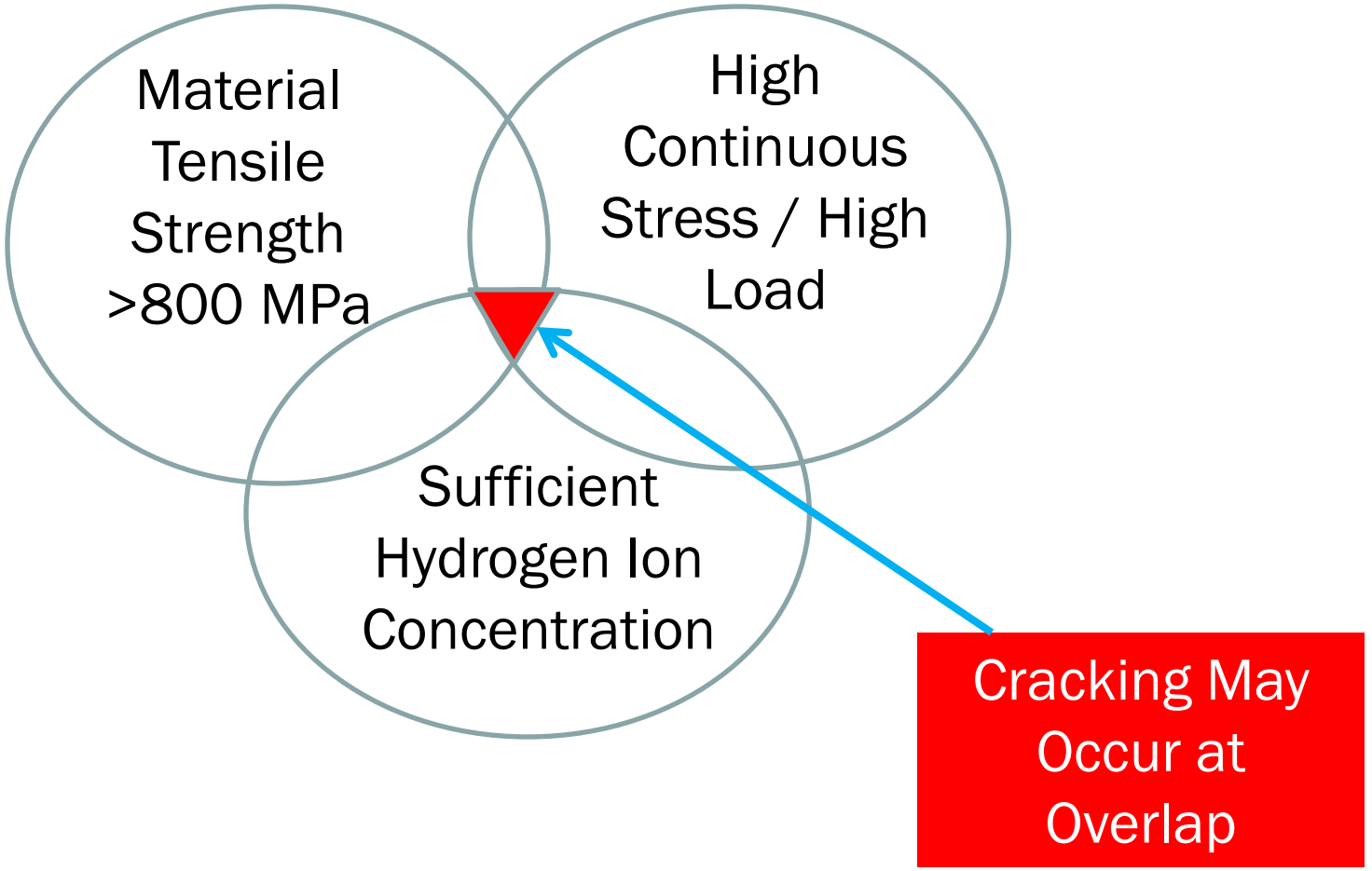
- The objective of the A/SP STHT was to select a known test that has high potential and “modify” the test to be able to differentiate automotive body materials susceptibility to hydrogen assisted cracking

Project Deliverables

- Test should be easy to run and be easily adapted for new grade validation
- Test can be modified for specific OEM pass/fail criteria.
- Test shall be applicable to sheet steel with or without additional manufacturing (coating, welding) or in-service corrosion inputs.

Note: It is commonly thought that the risk for hydrogen assisted cracking cannot be completely eliminated (in all potential processes/environments) unless tensile strengths are restricted to less than 800 MPa.

Hydrogen Assisted Cracking – Venn Diagram



Test Method Selection

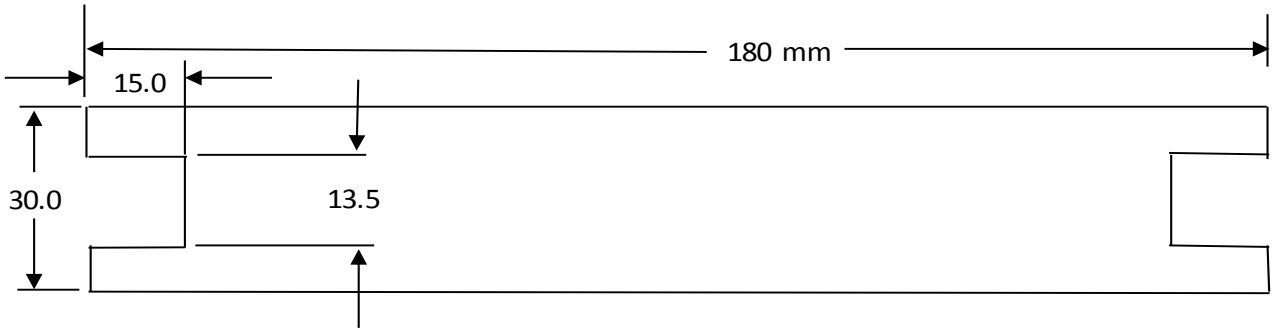
- After review of applicable tests, literature, and industry experience, it was decided that a simple test bend test could provide what is needed
- However, extensive testing showed that conventional bend tested samples, when exposed to acidic conditions, could not be made to crack with UHSS's that were available
- Fortunately, industry testing with bend test samples over large radii, strained to pre-determined stress levels, showed promise

Test Method Selection

- Shape Corp. found that a modified a JIS test bend test was appropriate
  - Was able to differentiate materials based on tensile strength and stress levels
  - Could be run on test coupons and finished parts
  - It exhibits an excellent level of material differentiation/ performance in the test
  - Material level testing correlated well to part level performance in the specified test environment
  - The results are consistent with current field experience

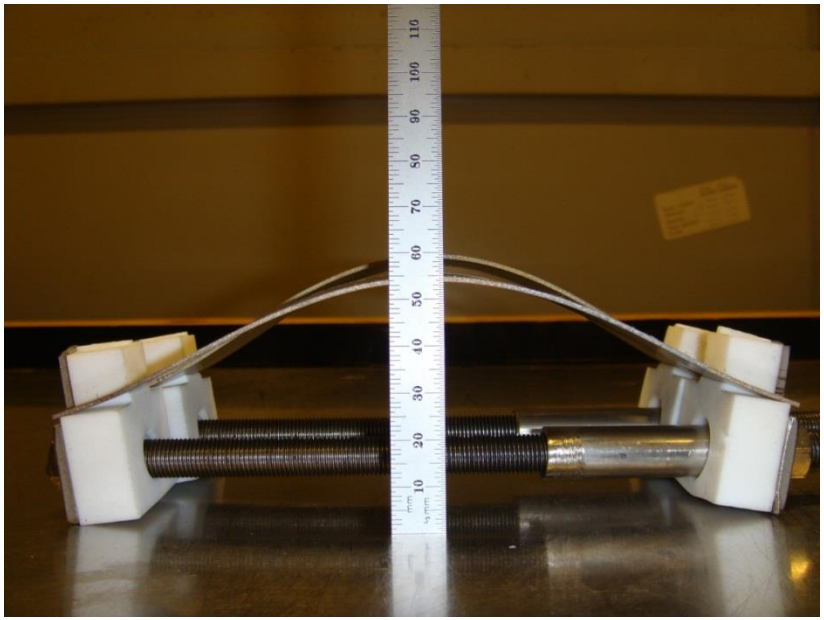
Test Method

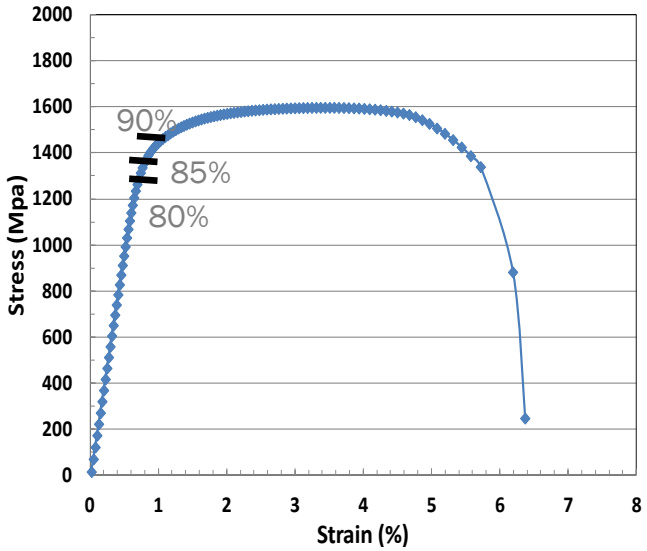
Test Sample Geometry



Test Method

Test Sample Geometry





- Samples are strain-gauged and bent to the desired stress levels
- Fixtured samples are immersed in 0.1 N hydrochloric acid

Test Method

pH ~1 (After 5 hrs)

Observation:

Susceptible materials at high strains, immersed in 0.1N HCl, show major cracks after relatively short exposures to the acid solution

Summary of U-bend Results

Tensile Strength (MPa)	Sample Stress Loads/Hours to Cracking			
	70% YS	80% YS	85% YS	90% YS
1417	NF	NF	NF	NF
1424	NF	NF	NF	NF
1599	NF	NF	NF	NF
1596	NF	NF	168 hrs & NF	5 hrs
1745	NF	NF	NF	NF
1765	NF	NF	NF	5 hrs
1788	NF	NF	NF	NF
1812	NF	NF	168 hrs & NF	5 hrs & NF
1819	NF	NF	NF	5 hrs
1855	NF	NF	40 hrs & NF	14-36
1908	NF	NF	36 hrs	5 hrs

Key: NF- No fracture
hrs - Hours

Data represents examples of specific steel grades. Results will vary depending on load, micro-structure/ strength as well as exposure conditions

Observations/Conclusions

- A bend test consisting of samples pre-strained to >/= 70% of their yield strength shows promise for evaluating hydrogen susceptibility
- Some material/microstructure combinations with high tensile strengths have been shown as susceptible to hydrogen assisted cracking when exposed to test conditions
- Hydrogen related cracks occur very early in the test.

Observations/Conclusions

- Multiple test labs have seen similar results when susceptible materials are evaluated to the new test method
- The A/SP Sheet Steel Harmonization Task Force is developing a draft test method. The Society of Automotive Engineers may be the publishing organization for this test method

Further Work

- Since it is unknown how much hydrogen will be absorbed by automotive steels in a service environment, precise correlation to field exposure is required
- Evaluation of fracture mechanisms of the bend test compared to observed field fracture mechanisms
  - Evaluate acceleration rates vs. mechanism
  - Fracture mechanism as a function of hydrogen exposure

Further Work

- The presence of sacrificial coatings on test samples needs further study. Limited testing has shown that hydrogen evolution on zinc coated samples can charge samples and lead to fracture
- The influence of biaxial and compressive strains on the rate of embrittlement needs investigation