Delayed Cracking of Advanced High Strength Steel Solutions

A/SP Steel Testing Harmonization Task Force

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Project Goals

- To develop a test method for ranking the relative susceptibility of zinc coated advanced high strength steels (AHSS) and ultra-high strength steels (UHSS) to hydrogen assisted cracking.
- To avoid the most common concerns with existing tests:
  - Artificial “charging” with hydrogen concentrations far above what would be expected in automotive environment
  - Development of a test that is not relevant to thin sheet steels
  - Development of a test that is complicated and/or requires R&D type of equipment

Project Goals

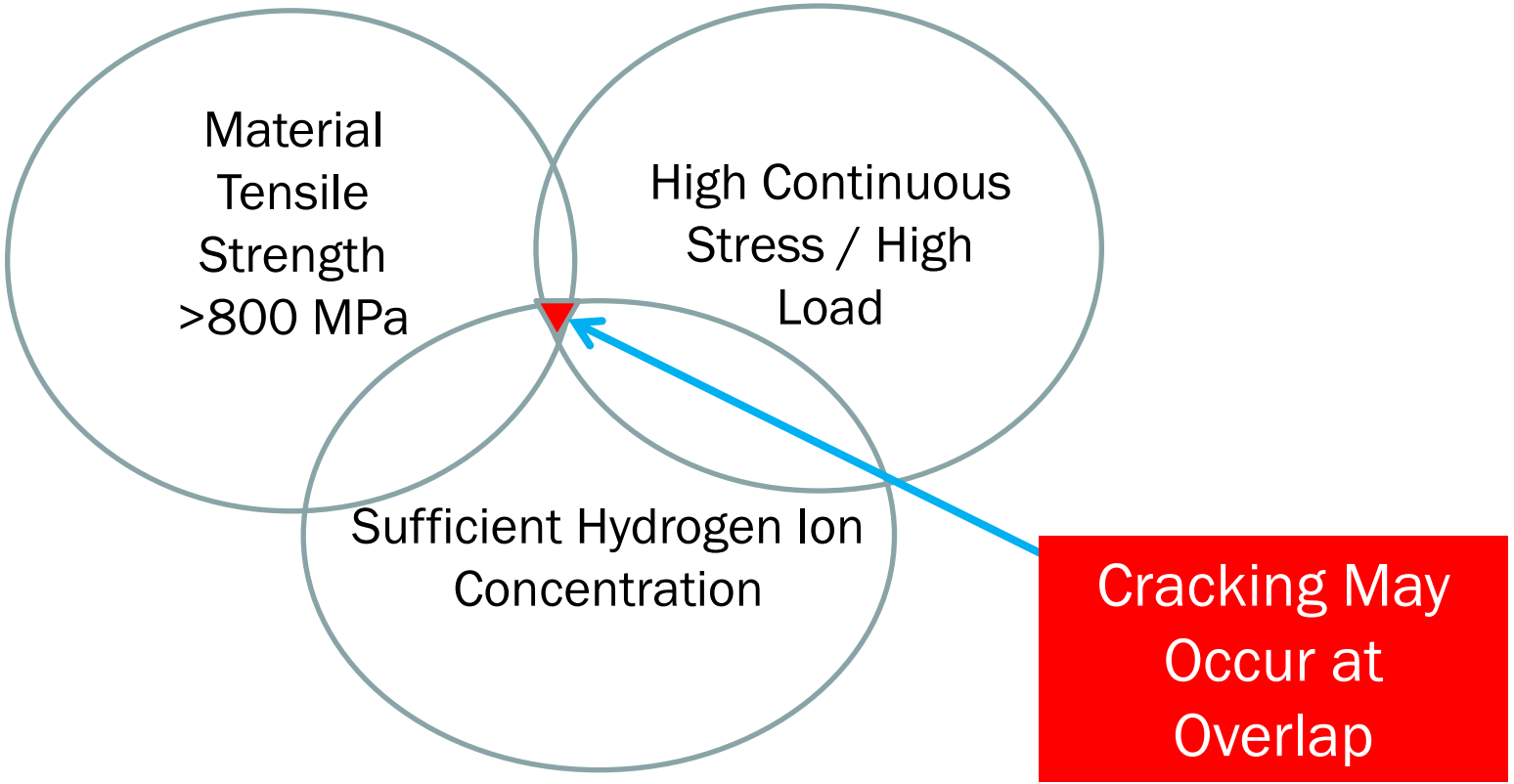
- To expand on the previous work done by the A/SP STHT which resulted in a draft procedure for determining the relative susceptibility of bare AHSS/UHSS
- To develop a representative test for zinc coated steels

Project Deliverables

- A test that is relatively easy to run and adapted for new grade validation
- A test that can be modified for specific OEM pass/fail criteria.
- A test that is applicable to sheet steel with or without additional manufacturing (coating, welding, etc.) 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 below 800 MPa

Hydrogen Assisted Cracking – Venn Diagram



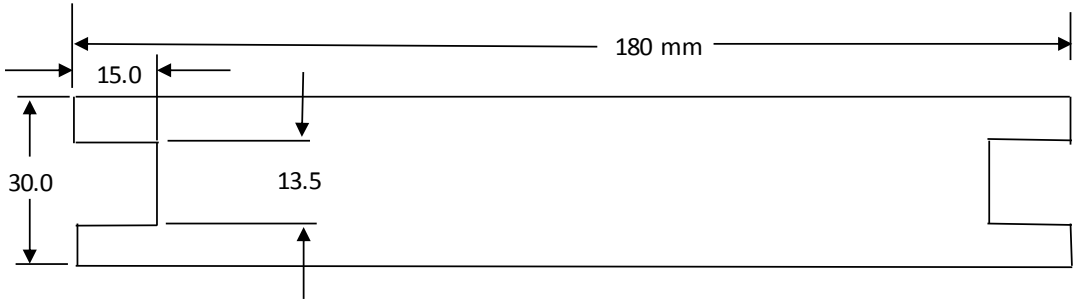
Previous Work Observations/Conclusions

- A bend test consisting of samples pre-strained to >/=70% of their yield strength shows promise for evaluating hydrogen susceptibility
- Some materials/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.

Previous Work Observations/Conclusions

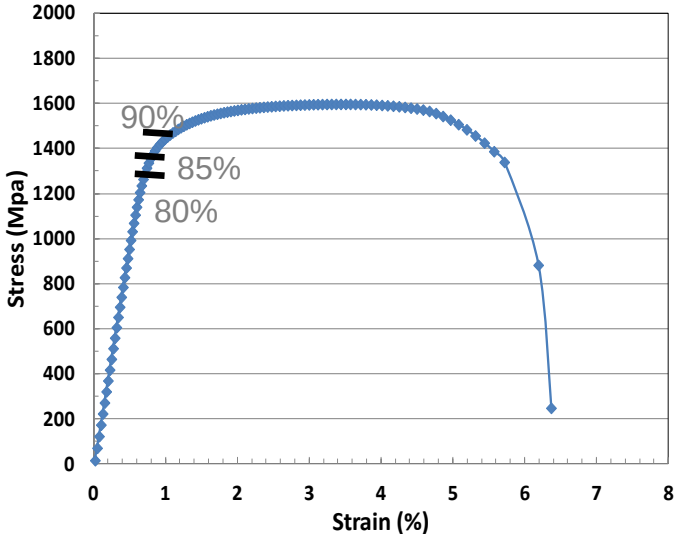
- Multiple test labs have seen similar results when susceptible materials are evaluated to the new test method.
- The A/SP Sheet Steel Harmonization Task Force has developed a draft test method for testing uncoated steels.
- When testing zinc coated steels with 0.1N HCl, the generation of hydrogen during dissolution can lead to premature fracture.

Test Sample Geometry



Test Method

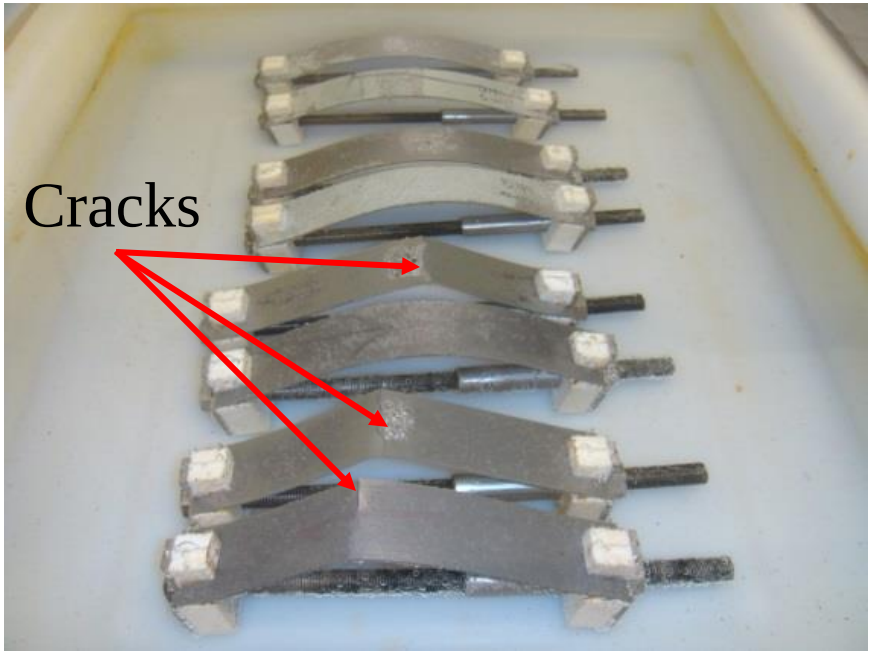
Test Sample Geometry



- 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, exhibit large cracks after relatively short exposures to the acid solution

Current Investigations

- Goal: Work with AET Integration, Inc. to determine adaptations needed to current draft procedure to allow testing of grades with zinc coatings
- Comparison of different concentrations of hydrogen source (NH_4SCN) to previously studied HCl.
- Testing of dual phase, fully martensitic and press hardened grades

Test Matrix

Material			Strain Level of Test (% of Yield Stress)				Solution Concentration		Specimens	
Material Grade	Thickness	Coating					0.1N HCl	NH_4SCN	# of Runs	Specimens (3 Replicates)
DP780T/420Y	1.0	HDGI	100%				1	3/5	6	18
DP980/550Y	1.2	Bare	100%				1	3/3	4	12
	1.2	EG	100%				1	3/3	4	12
MP980T/700Y LCE	1.4	Bare	100%	TBD	TBD		1	3	12	36
MP980T/700Y LCE	1.4	EG	100%				1	3/3	4	12
MS1500T/1200Y	1.4	EG	100%	TBD	TBD		1	3	12	36
	1.0	Bare	100%	90%	80%	60%	1	3/5	24	72
	1.0	EG	100%	90%	80%	60%	1	3/5	24	90
MS1700T/1350Y	1.0	Bare	100%	TBD	TBD	TBD	1	5	30	90
HS1300T/950Y PHS	1.0	Bare	100%	TBD	TBD	TBD	1	5	20	90
	1.0	AlSi	100%	TBD	TBD	TBD	1	5	30	90
	2.0	AlSi	100%	TBD	TBD	TBD	1	5	30	90

* All samples ran with bend parallel to rolling direction

** All samples ran with shear edge on top of bend specimens (in tension)

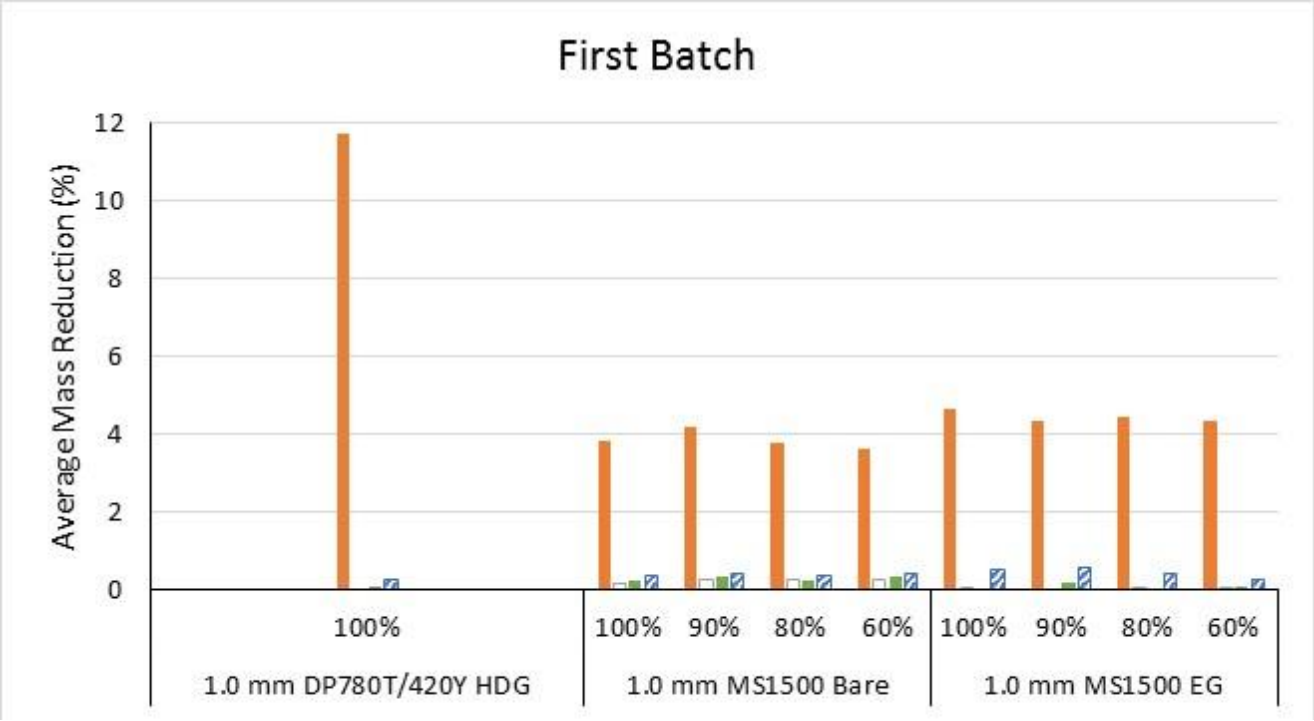
Test Results – First Batch

Material	Solution	Initial pH	% of Yield Strength Tested	Total Specimens	Number of Specimens Cracked
1.0mm DP780T/420Y HDGI	0.1N HCL	1.04	100%	3	0
	0.1% NH_4SCN	5.60	100%	3	0
	0.3% NH_4SCN	5.50	100%	3	0
	1.0% NH_4SCN	6.06	100%	3	0
1.0mm MS1500 Bare	0.1N HCL	1.00	100%, 90%, 80%, 60%	12	0
	0.1% NH_4SCN	6.73	100%, 90%, 80%, 60%	12	0
	0.3% NH_4SCN	5.40	100%, 90%, 80%, 60%	12	12
	1.0% NH_4SCN	5.57	100%, 90%, 80%, 60%	12	11
1.0 mm MS 1500 EG	0.1N HCL	1.08	100%, 90%, 80%, 60%	12	11
	0.1% NH_4SCN	5.73	100%, 90%, 80%, 60%	12	10
	0.3% NH_4SCN	5.38	100%, 90%, 80%, 60%	12	12
	1.0% NH_4SCN	5.86	100%, 90%, 80%, 60%	12	12

Auto/Steel Partnership

AET INTEGRATION

Average Mass Reduction (%) – First Batch



Auto/Steel Partnership

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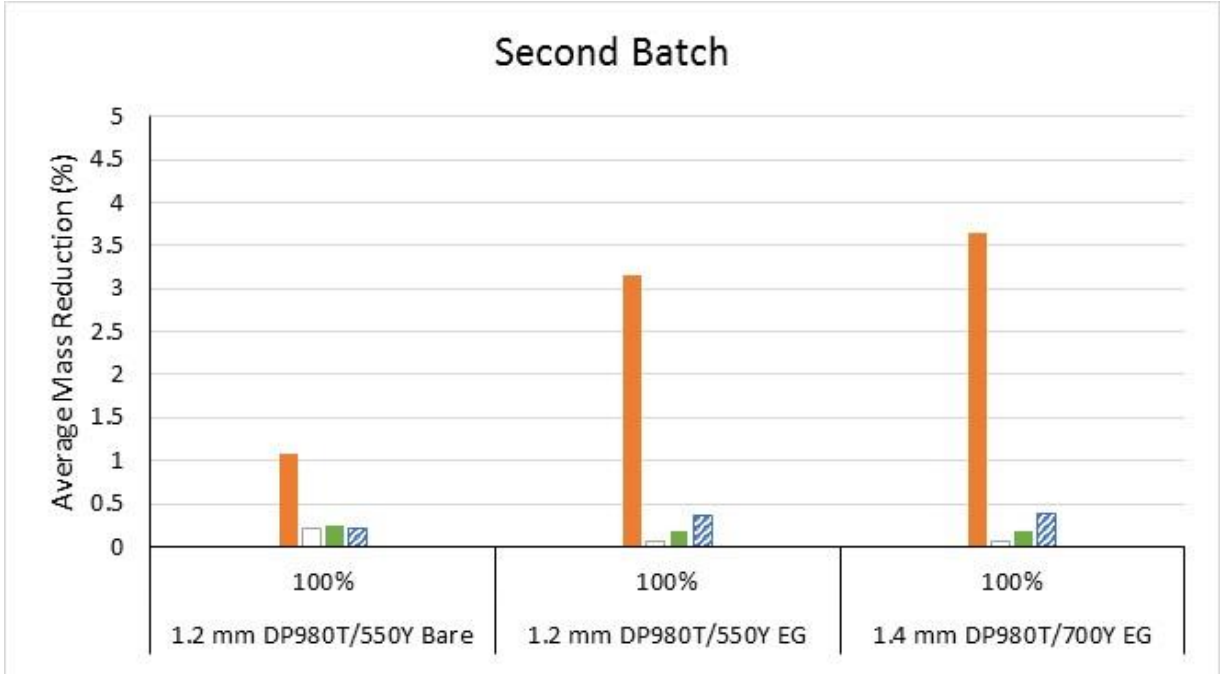
Test Results – Second Batch

Material	Solution	Initial pH	% of Yield Strength Tested	Total Specimens	Number of Specimens Cracked
1.2mm DP980T/550Y Bare	0.1N HCL	1.05	100%	3	0
	0.1% NH_4SCN	5.52	100%	3	0
	0.3% NH_4SCN	5.42	100%	3	0
	1.0% NH_4SCN	5.09	100%	3	0
1.2mm DP980T/550Y EG	0.1N HCL	1.05	100%	3	0
	0.1% NH_4SCN	5.48	100%	3	0
	0.3% NH_4SCN	5.36	100%	3	0
	1.0% NH_4SCN	5.04	100%	3	1
1.2mm DP980T/700Y EG	0.1N HCL	1.04	100%	3	0
	0.1% NH_4SCN	5.48	100%	3	0
	0.3% NH_4SCN	5.37	100%	3	0
	1.0% NH_4SCN	5.04	100%	3	0

Average Mass Reduction (%) – Second Batch



Current Observations

- Use of NH_4SCN resulted in a significantly lower attack on the coatings than the previously used HCl
- The lower rate of attack on the zinc coatings in the NH_4SCN solutions (ie low mass loss), likely resulted in low/little hydrogen evolution and lower amounts of hydrogen absorption

Conclusions

- The use of a NH_4SCN solution appeared to greatly reduce or eliminate hydrogen evolution of zinc coated AHSS's
- The use of NH_4SCN does show promise as an alternative test solution to .1N HCL, however, lower concentrations than those tested need to be evaluated for use on zinc coated substrate

Areas of Possible Future Work

- Investigate lower concentrations of NH_4SCN
- Investigate techniques for coating removal
  - Follow with acid immersion bend test
  - Test coated substrate to SEP1970 – Tensile Specimen with Punched Hole
  - Others?

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