REX2024
PRCI Research Exchange

Hard Spot Panel Discussion

Hard Spot Fitness-for-Service

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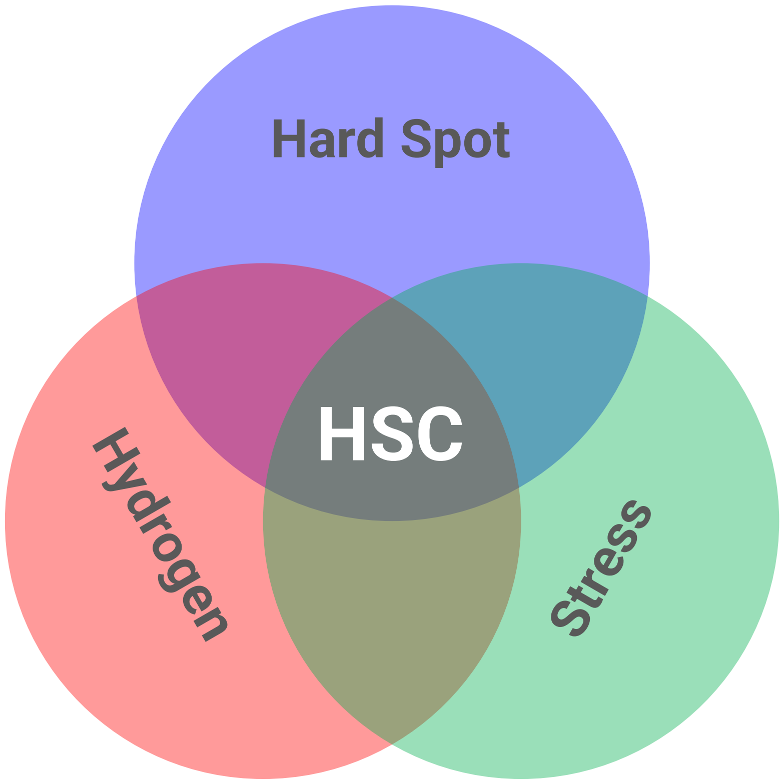
San Diego, California
February 28, 2024

PRCI LEADING PIPELINE RESEARCH

Pipeline Research Council International

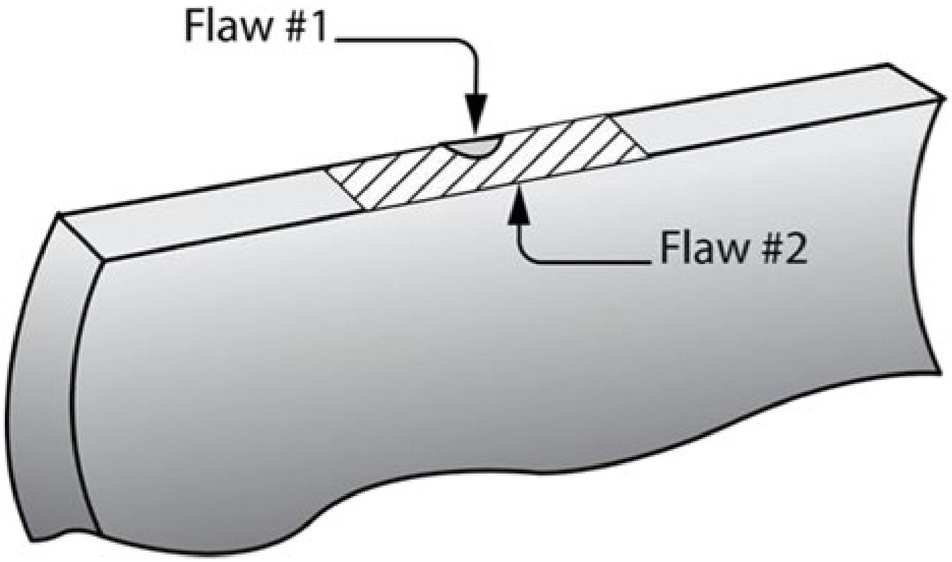
Fitness-for-Service Considerations

- **Hydrogen embrittlement**
  - Hardened material has higher susceptibility
  - Leads to low fracture toughness
  - **Resistance to crack growth ↓**
- **Hydrogen stress cracking susceptibility**
  - Harder material, higher susceptibility
  - **Likelihood of crack formation ↑**
- **Hard spot size**
  - Larger hard spot means greater length of brittle material for crack to propagate through
  - **Probability of rupture before leak ↑**



Deterministic Model

- Flaw #1: Thumbnail crack initiated due to hydrogen stress cracking
- Rapid crack growth due to low fracture toughness in hard spot
- Flaw #2: Through-wall crack length of hard spot
- What happens next?
  - Rapid crack growth continues into unhardened material (rupture)
  - Crack growth arrested at edge of hard spot (leak)

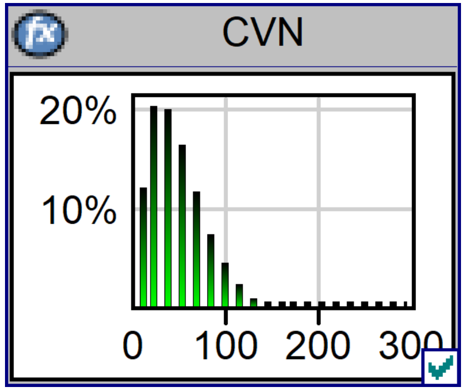


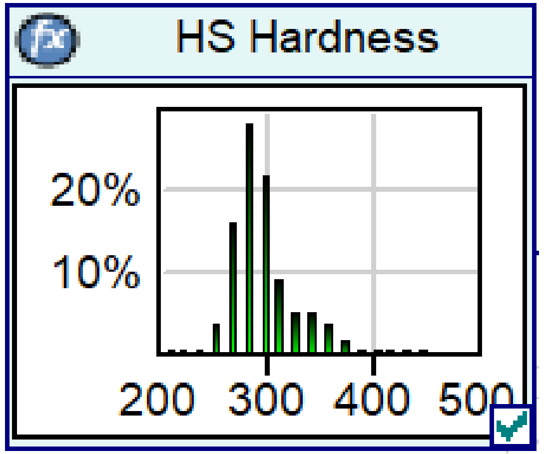
Deterministic Model

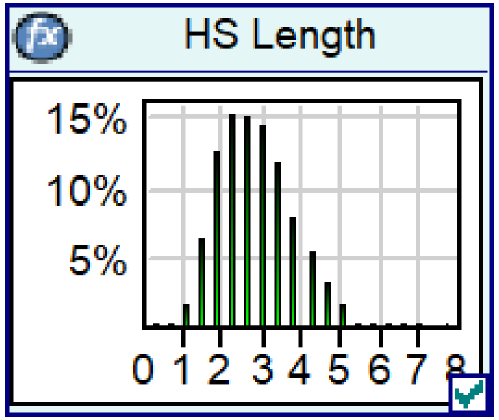
- **Presence of crack is assumed**
- **Model prediction hinges on dynamic fracture toughness of unhardened material**
- **Critical parameters**
  - Dynamic fracture toughness (calculated from CVN)
  - Hard spot length
  - Operating stress
- **Thoughts to consider**
  - Like hard spots, dynamic fracture toughness is associated with plate manufacturer
  - What is the length of the low-toughness area? Length of the hard spot?
  - What is the hardness threshold for HSC?

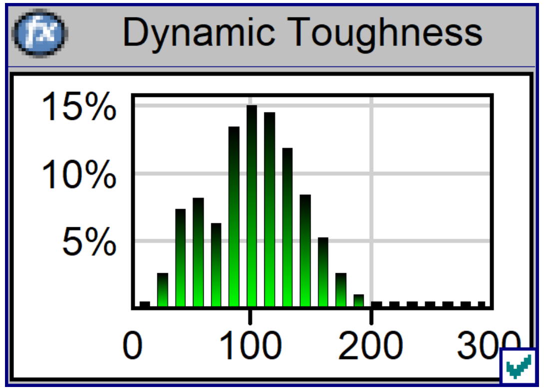
Probabilistic Model

- **Conceptual approach**
  - Randomly sample input parameters
  - Determine if inputs results in rupture using deterministic model
  - Repeat and count number of ruptures versus non-ruptures → probability of failure
- **Challenges**
  - Need data to create distributions for inputs
  - At a minimum, need SME input
  - Acceptable risk targets









Probabilistic Model

- **Motivation for probabilistic approach**
  - We don’t always have hard numbers for all the inputs
  - Even when we have the inputs, there is still uncertainty
  - Evaluating hypothetical operating scenarios
- **Probabilistic model can account for aleatory and epistemic uncertainty**
- **Can be applied with mixed deterministic and probabilistic inputs**
- **Inputs can be generated from system generic data, data from like pipe, or segment specific data**

How is this useful?

- **Susceptibility models (pre-ILI)**
  - Where to look for hard spots?
  - Manufacturer and/or vintage specific inputs for CVN, hard spot length, hardness, etc.
  - Incorporate coating susceptibility and CP effects
- **Hard spot integrity management (post-ILI)**
  - Which hard spots to verify? How to prioritize?
  - Model ILI uncertainty → probability of exceedance
- **ILI verification**
  - In-ditch NDE tools and hardness mapping
  - Feedback to improve ILI and recalibrate susceptibility models