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GTI/OTD – Crack Modeling Roadmap

Managing Pipeline Cracking Challenges Workshop
Tuesday, August 5, 2014
Crowne Plaza Hotel, Rosemont, IL
Panel 4: Presentation of Research Roadmaps

OTD Operations Technology Development

gti

GTI/OTD Program for Crack and Damage Propagation

- GTI's efforts related to crack initiation and damage propagation in gas and liquid pipelines are integral to two GTI program areas:
  - Risk and Decision Analysis
  - Inspection and Verification
- >$2 million in projects directly related to damage propagation completed or initiated in last 4 years
- Focused on practical deliverables with solid technical underpinnings

GTI RDA Program Overview

- GTI's Risk and Decision Analysis (RDA) program provides reasons to stakeholders and auditors for decisions related to utility infrastructure design and operations.
- The program employs a multidisciplinary process that includes risk assessment, characterization, communication and management, and related optimization of decisions.
- The output of the program includes predictive models, calculators, and databases that describe the complex and interconnected behavior of utility infrastructure systems and their risks.

IV Program Overview

> GTI's Inspection and Verification (IV) program is developing and deploying inspection and analysis models and technology which allow operators to:
  - **select** appropriate inspection tools,
  - **assess** their pipeline systems for defects, and
  - **verify** their pipeline and fitting material and chemical properties

> These technologies and models benefit operators by allowing them to:
  - **meet Integrity Verification Process (IVP) requirements** for establishing MAOP and material condition of assets
  - **conduct recurring integrity assessments** required by statutory code
  - **perform fitness-for-service** of in-service components

EXAMPLE 1 (RDA Program)

Leak Rupture Boundary Model

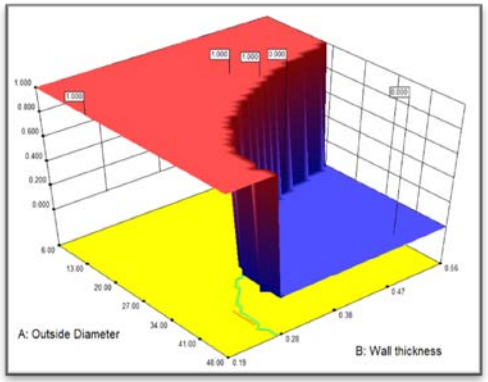
> **Background**

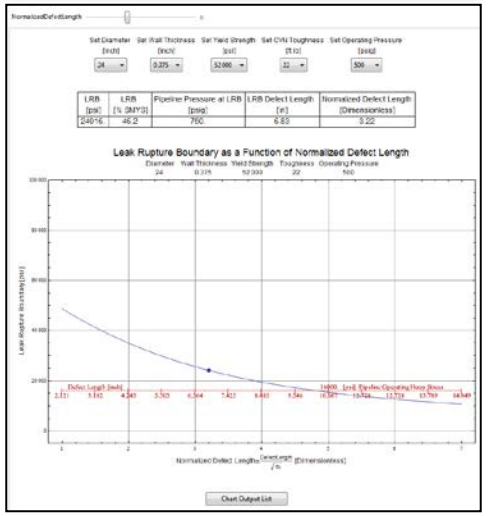
- Need for a validated model and statistical analysis to develop a leak-rupture calculation based on theory, but that incorporates typical industry uncertainty/variability of measurements, and provided confidence levels.

> **Objective**

- Develop a tool to predict whether a pipe will fail by leak or by rupture based on material properties to assist operators in determining the consequence of failure for individual pipe segments based on pipe characteristics

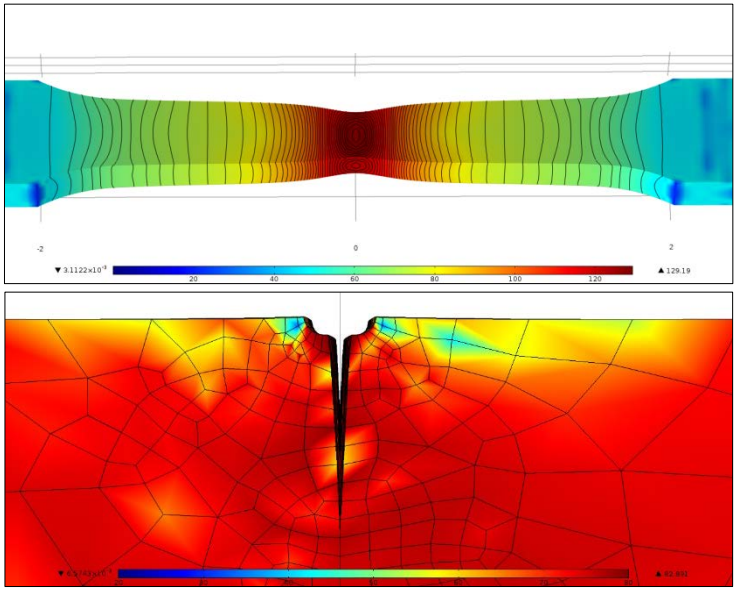
> **Deliverable – a software tool with training manual that outputs the mode of failure (leak or rupture) based on inputs (yield strength, toughness, diameter, wall thickness) with a stated confidence level**





EXAMPLE 2 (RDA Program)

Advanced Crack Propagation Model



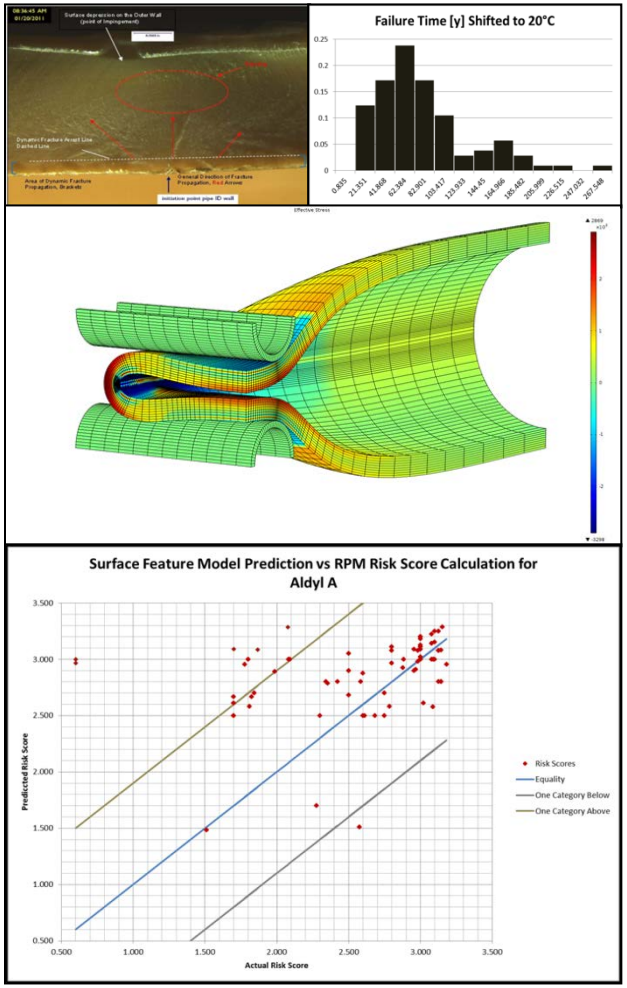
> **Background**
  - With recent ruptures and new pending regulations, there will be increased hydrotesting of vintage pipelines which could lead to an increase in latent damage of certain pipeline categories

> **Objective**
  - To develop and validate a model that correlates pressurizations to crack growth rates
  - Identify high risk pipe segments based on historical pressurization records

> **Deliverable – a software tool and associated model with the ability to predict the impact on pipe integrity of hydro-testing and spike testing as well as select the optimal operating pressure**

Damage Propagation in Viscoelastic Materials

- **Background –** Vintage plastic (Aldyl A) piping systems are nearing the end of their design life in many gas distribution systems. These materials are susceptible to cracking and premature failure. There is a need to prioritize replacement programs based on objective assessment of the likelihood of failure.
- **Objective –** Develop a comprehensive set of models to predict residual lifetime based on the likelihood of damage initiation and the rate of propagation of the damage.
- **Deliverable – a probabilistic risk assessment tool that has advanced crack initiation modeling and propagation methods at its core**



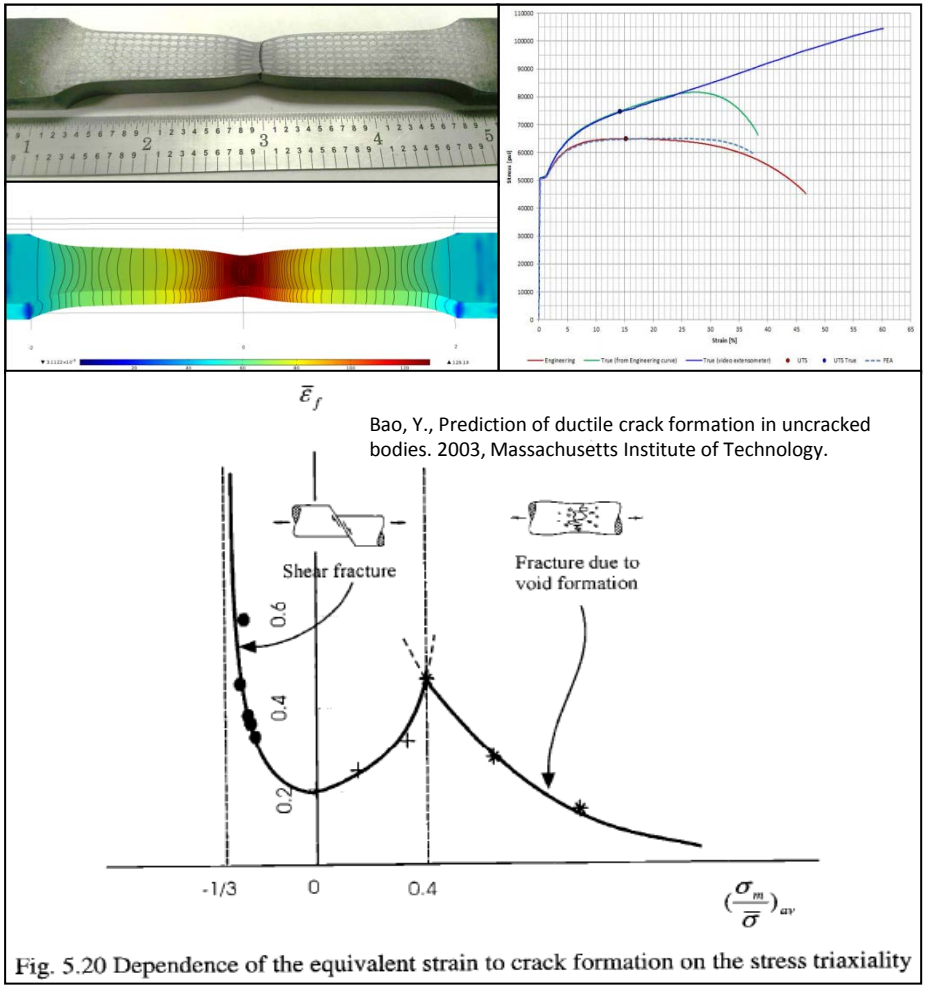
EXAMPLE 4 (IV Program)

Enabling Alternatives to a Hydrotest

- **Value**
  - ILI tools may have the ability to detect defects that would fail a hydrotest, allowing for equivalent tests for lines that are not receptive to hydrotesting due to design, material considerations, or other issues
  - ILI tools have the further advantage of characterizing and finding sub-critical defects (could be just under the size that would fail a hydrotest), therefore identifying high risk situations not detected by a hydrotest
- **Objective**
  - **Define critical flaw sizes to create critical flaw and metal loss curves for different pipe materials, diameter, wall thicknesses**
  - Identify which ILI tools can detect the critical flaws by comparing critical flaw and metal loss values to inspection tool POD and tool tolerances.
- **Deliverable - a calculator that operators can use to select ILI tools for specific pipe segments as an alternative to hydrotesting; also incorporate the methodology into an industry standard**

Challenges and Future Efforts

- Develop comprehensive library of pipeline material properties
  - True stress/strain curves
  - Toughness
- Develop constitutive models necessary for viscoelastic and plastic analysis using FEM
- Refine FEM models capable of modeling brittle, ductile and shear fractures under any loading and geometry condition



Bao, Y., Prediction of ductile crack formation in uncracked bodies. 2003, Massachusetts Institute of Technology.

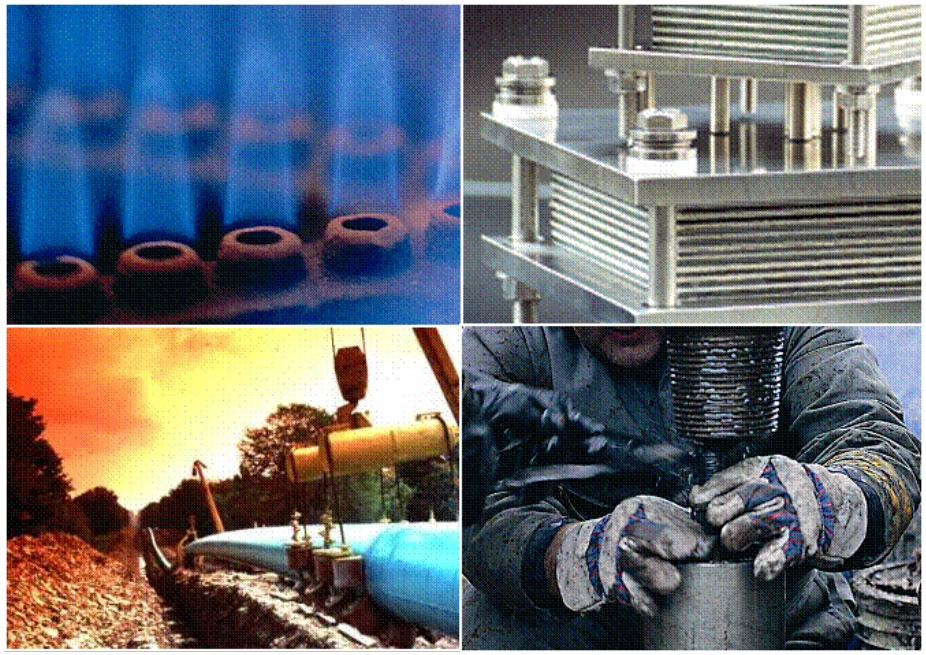
Fig. 5.20 Dependence of the equivalent strain to crack formation on the stress triaxiality

Thank You

> We thank PHMSA for the opportunity to participate in this workshop and to present our crack related research projects

> We would also like to thank the Operations Technology Development Company (OTD) for their considerable financial support, guidance and encouragement for the research we presented today.

Questions?



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