PROBABILISTIC FRACTURE MECHANICS TOOLKIT FOR HYDROGEN BLENDS IN NATURUAL GAS INFRASTRUCTURE

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Hydrogen is known to cause embrittlement of virtually all steels, including pipeline steels. To address hydrogen-assisted fatigue and fracture, ASME developed a code for Hydrogen Piping and Pipelines (B31.12), which provides a conservative and deterministic approach to structural integrity. However, structural integrity of large assets, such as pipelines, is intrinsically a probabilistic problem since knowledge of the defects is necessary, but uncertain in nature. Knowing the extent to which this embrittlement will impact the pipeline's instantaneous and temporal structural integrity will inform stakeholders on operational and economic implications. As part of the Pipeline Blending CRADA (a HyBlend™ project), a modular probabilistic fracture mechanics platform coined Hydrogen Extremely Low Probability of Rupture (HELPR) is being developed to assess structural integrity of natural gas infrastructure for transmission and distribution of hydrogen natural gas blends. HELPR contains fatigue and fracture engineering models allowing fast computations, while its probabilistic framework enables exploration and characterization of the sensitivity of predicted outcomes to uncertainties of the pipeline structure and operation. Examples of uncertain structural-integrity model inputs include material properties (e.g., fatigue crack growth and fracture resistance), structural variables (e.g., pre-existing crack / defect size and pipe dimensions), as well as environmental conditions (e.g., hydrogen partial pressure and pressure variations). Figure 1 provides an illustration of how HELPR's probabilistic capability enables characterization of prediction sensitivity. Uncertainty sources are specified as being either epistemic and aleatoric (also known as lack-of-knowledge and inherent variability), allowing HELPR to simultaneously investigate and characterize expected variability within a population and the impact of the current state of knowledge.

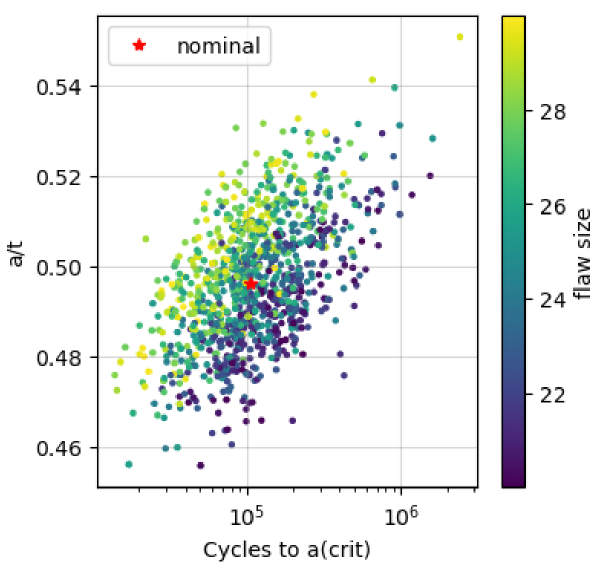

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Figure 1 – Demonstration of HELPR's sensitivity results, showing impact of flaw size (marker color) on the number of cycles to the critical flaw size a(crit) and critical crack size normalized by the pipe thickness a/t.