Materials Science & Engineering Doctoral Defense

Statistical models for prediction of mechanical property and manufacturing process parameters for gas pipeline steels

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abstract

Pipeline infrastructure forms a vital aspect of the United States economy and standard of living. A majority of the current pipeline systems were installed in the early 1900's and often lack a reliable database reporting the mechanical properties, and information about manufacturing and installation, thereby raising a concern for their safety and integrity. Testing for the aging pipe strength and toughness estimation without interrupting the transmission and operations thus becomes important. The state-of-the-art techniques tend to focus on the single modality deterministic estimation of pipe strength and do not account for inhomogeneity and uncertainties, many others appear to rely on destructive means. These gaps provide an impetus for novel methods to better characterize the pipe material properties. The focus of this study is the design of a Bayesian Network information fusion model for the prediction of accurate probabilistic pipe strength and consequently the maximum allowable operating pressure. A multimodal diagnosis is performed by assessing the mechanical property variation within the pipe in terms of material property measurements, such as microstructure, composition, hardness and other mechanical properties through experimental analysis, which are then integrated with the Bayesian network model that uses a Markov chain Monte Carlo (MCMC) algorithm. Prototype testing is carried out for model verification, validation and demonstration and data training of the model is employed to obtain a more accurate measure of the probabilistic pipe strength. With a view of providing a holistic measure of material performance in service, the fatigue properties of the pipe steel are investigated. The variation in the fatigue crack growth rate (da/dN) along the direction of the pipe wall thickness is studied in relation to the microstructure and the material constants for the crack growth have been reported. A combination of imaging and composition analysis is incorporated to study the fracture surface of the fatigue specimen. Finally, some well-known statistical inference models are employed for prediction of manufacturing process parameters for steel pipelines. The adaptability of the small datasets for the accuracy of the prediction outcomes is discussed and the models are compared for their performance.

November 7, 2018; 10 AM; ECG 218