Mechanical Engineering Thesis Defense

Data-Driven Approaches for Fatigue Prediction of Additively Manufactured Ti-6AL-4V and Simulation of Surface Defect Effect on Pipelines

School for Engineering of Matter, Transport and Energy

Rakesh Balamurugan

Advisor: Yongming Liu

Abstract

This study presents a comprehensive approach to address challenges in additive manufacturing (AM), fatigue life prediction, and pipeline integrity assessment. The study's primary objective is to develop and evaluate digital twins models that accurately predict crack initiation sites, fatigue life, and burst pressure in relevant applications.

The first part proposes a classification model to identify crack initiation sites in AM-built Ti-6Al-4V alloy. The model utilizes surface and pore-related parameters and achieves high accuracy (0.97) and robustness (F1 score of 0.98). Leveraging CT images for characterization and data extraction from the CT-images built STL files, the model effectively detects crack initiation sites while minimizing false positives and negatives. Data augmentation techniques, including SMOTE+Tomek, address imbalanced data distributions and improve model performance.

A novel Hybrid Physics Guided Neural Network (HPgNN) was proposed for fatigue life prediction. The surface roughness parameters of the LPBF Ti-6Al-4V alloy were used to train the HPgNN to surpass traditional neural network fatigue life prediction. Physics constraints are integrated into the neural network architecture, enabling more accurate predictions and reliable confidence bounds. The model demonstrates good learning capacity and generalization, providing accurate fatigue life predictions to unseen examples.

An elastic-plastic Finite Element Model (FEM) is developed in the second part to assess pipeline integrity, focusing on burst pressure estimation in high-pressure gas pipelines with interactive corrosion defects. The FEM accurately predicts burst pressure and evaluates the remaining useful life by considering the interaction between corrosion defects and neighboring pits. The FEM outperforms the well-known ASME-B31G method in handling interactive threats through accurate material properties, appropriate boundary conditions, and mesh refinement.

The models presented in this study serve different purposes within their respective domains. The classification model achieves high accuracy and robustness, enabling accurate crack initiation site prediction. The HPgNN for fatigue life prediction integrates physics constraints, providing improved predictions and reliable confidence bounds. The elastic-plastic FEM for burst pressure estimation excels in assessing pipeline integrity by considering interactive corrosion defects.

This study advances predictive models in AM crack detection, fatigue life prediction, and pipeline integrity assessment.

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