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Physics-Informed Neural Network for Predicting Strain Demand in Inelastic Pipes under Ground Movement with Geometric and Soil Resistance Nonlinearities

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Abstract : Buried pipelines play a crucial role in the transportation of energy products such as oil, gas, and various chemical fluids, ensuring their efficient and safe distribution. However, these pipelines are often susceptible to ground movements caused by geohazards like landslides, fault movements, lateral spreading, and more. Such ground movements can lead to strain-induced failures in pipes, resulting in leaks or explosions, leading to fires, financial losses, environmental contamination, and even loss of human life. Therefore, it is essential to study how buried pipelines respond when traversing geohazard-prone areas to assess the potential impact of ground movement on pipeline design. As such, this study introduces an approach called the Physics-Informed Neural Network (PINN) to predict the strain demand in inelastic pipes subjected to permanent ground displacement (PGD). This method uses a deep learning framework that does not require training data and makes it feasible to consider more realistic assumptions regarding existing nonlinearities. It leverages the underlying physics described by differential equations to approximate the solution. The study analyzes various scenarios involving different geohazard types, PGD values, and crossing angles, comparing the predictions with results obtained from finite element methods. The findings demonstrate a good agreement between the results of the proposed method and the finite element method, highlighting its potential as a simulation-free, data-free, and meshless alternative. This study paves the way for further advancements, such as the simulation-free reliability assessment of pipes subjected to PGD, as part of ongoing research that leverages the proposed method.

Keywords : strain demand, inelastic pipe, permanent ground displacement, machine learning, physics-informed neural network
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