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Title of Thesis: Response Prediction of Steel Pipeline and Strengthened with Different Innovative Techniques under Different TNT Explosion Scenarios: CEL-FEM Approach

FINDINGS

This study greatly enhances knowledge of steel pipeline durability in TNT explosion scenarios, utilizing the Coupled Eulerian-Lagrangian Finite Element Method (CEL-FEM) in ABAQUS/Explicit. Through validating numerical models and assessing mitigation approaches under varied blast conditions, it fills key gaps in the literature on pipeline blast resistance. Chapter 4 confirmed the accuracy of an empty pipeline model under contact and non-contact (25 mm and 50 mm standoff) blast conditions, achieving a solid baseline with deformation errors as low as 1.68% relative to experimental results. This validation demonstrated the effectiveness of CEL-FEM in modeling fluid-structure interactions, supporting dependable parametric studies. Chapter 5 showed that internal water levels (from one-quarter to full) decreased deformation from 34.41 mm to 2.24 mm and plastic damage energy from 119 J to 17.05 J, underscoring water's effectiveness as an economical, passive damping medium. Chapter 6 demonstrated that carbon fiber reinforced polymer (CFRP) laminates (0.15 mm to 0.75 mm for contact blasts, 2 mm for internal blasts) decreased deformation by up to 99.65% and plastic damage energy by 99.66%, providing a lightweight, corrosion-resistant retrofitting option. Chapter 7 evaluated UHPC, aluminum foam, titanium foam, and CFRP coatings, with CFRP (0.75 mm) yielding the lowest deformation (0.16 mm) and plastic damage energy (0.41 J), followed by titanium foam (3.54 mm, 6.5 J), aluminum foam (11.14 mm, 31.6 J), and UHPC (85.46 mm, 198–210 J).

Key contributions involve demonstrating the inverse correlation between standoff distance and damage, highlighting water's damping effectiveness, and confirming CFRP's exceptional blast mitigation performance. The study offers a validated numerical framework for simulating complex blast scenarios, including contact, subsurface, above-surface, and internal explosions, using accurate material models (Johnson-Cook for steel, JWL EoS for TNT, Hashin's criteria for CFRP). These results provide practical retrofitting solutions for pipelines in blast-prone areas, improving safety and operational reliability.