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Mechanical Behavior of Corroded Aluminum Tanks Repaired with Composite Patches: A Numerical Investigation and Experimental Stiffness Validation

Leila Belkaddour[a], Sidi Mohamed Medjdoub[b], Mostefa Hani[c], Ahmed Belaadi[d], Ali Ercetin[e,f], Yazid Chetbani[g], Adhya-Eddine Hamitouche[g], and Herbert Mukalazi[h]

[a]Faculty of Technology, Department of Mechanical Engineering, Laboratory of Industrial Engineering & Sustainable Development (GIDD), University of Ahmed Zabana Relizane, W. Relizane, Algeria; [b]Department of Mechanical Engineering, University of Sidi Bel Abbes, Sidi Bel Abbes, Algeria; [c]Department of Civil Engineering and Hydraulics, Faculty of Sciences and Technology, Jijel University, Jijel, Algeria; [d]Department of Mechanical Engineering, Faculty of Technology, University of Skikda, El-Hadaiek, Algeria; [e]Department of Naval Architecture and Marine Engineering, Maritime Faculty, Bandırma Onyedi Eylul University, Bandırma, Türkiye; [f]University College, Korea University, Seoul, Republic of Korea; [g]Centre de Recherche scientifique et Technique en Analyses Physico-Chimiques CRAPC, Tipaza, Algeria; [h]Department of Mathematics and Statistics, Kyambogo University, Kampala, Uganda

ABSTRACT

To enhance the structural durability of degraded metallic assets, this study investigates an advanced repair strategy for corroded aluminum tanks using composite patches. An epoxy matrix reinforced with four distinct fiber types high-performance synthetic (carbon, boron, glass) and eco-friendly natural (flax) is evaluated to balance mechanical restoration with environmental sustainability. The methodology relies on a combined numerical-experimental validation framework. Finite element analysis (FEA) is conducted via ABAQUS to comprehensively map Von Mises stress distributions within the repaired zone as a function of defect length, internal pressure, and three distinct defect orientations (longitudinal, transverse, and circumferential). In parallel, experimental tensile testing of repaired specimens is performed to assess the global mechanical response of the structure and to validate the effectiveness of the composite patching strategy under service-like loading conditions. The results reveal that corrosion orientation critically governs repair efficiency. Carbon/epoxy patches applied over circumferential defects yield the highest mechanical resilience, successfully restoring structural integrity. While the bio-based flax/epoxy patches exhibit lower absolute strength than their synthetic counterparts, they deliver substantial structural reinforcement. Ultimately, this validated framework provides a powerful tool to optimize composite patch repairs, paving the way for reliable, sustainable, and eco-friendly maintenance in industrial pressure vessel applications.

KEYWORDS

Corroded aluminum; experimental validation; Finite Element Analysis; Von Mises stress; corrosion orientation; Bbio-composites

關鍵詞

受蝕鋁材; 實驗驗證; 有限元素分析; 馮·米塞斯應力; 腐蝕取向; 生物複合材料

HIGHLIGHTS

- A coupled experimental – numerical approach is employed to study composite repairs of corroded cylinders.
- Both synthetic composites (carbon/epoxy, glass/epoxy, boron/epoxy) and a natural flax/epoxy biofiber are investigated.
- The influence of corrosion orientation (longitudinal, transverse, circumferential) and internal pressure is analyzed.
- The study provides insights into load transfer mechanisms and repair efficiency.
- Flax/epoxy biofiber shows promising potential as a sustainable and eco-friendly alternative to synthetic composites.

摘要

為提升劣化金屬資產的結構耐久性，本研究針對受腐蝕的鋁製儲槽，探討採用複合材料補片進行修復的先進策略。研究評估了一種由四種不同纖維類型 (高性能合成纖維: 碳纖維、硼纖維、玻璃纖維; 環保天然纖維: 亞麻纖維)增強的環氧樹脂基體，以在機械性能恢復與環境永續性之間取得平衡。本研究方法採用數值與實驗結合的驗證框架。透過 ABAQUS 進行有限元素分析 (FEA)，以全面繪製修復區域內馮·米塞斯應力分布圖，並將其與缺陷長度、內部壓力以及三種不同的缺陷取向 (縱向、橫向及周向)

CONTACT Ahmed Belaadi ahmedbelaadi1@gmail.com Department of Mechanical Engineering, Faculty of Technology, University of Skikda, El-Hadaiek, Algeria; Herbert Mukalazi hmukalazi@kyu.ac.ug Department of Mathematics and Statistics, Kyambogo University, Kampala, Uganda