J. Energy Conversion
Volume: 11, Issue 4, 2025, 65-85

نشریه علمی-تخصصی تبدیل انرژی (JEED)

دوره ۱۱، شماره ۴، زمستان ۱۴۰۳، ص: ۸۵-۶۵

Fabrication, modeling and fluid analysis of a composite sandwich panel with a lattice core for use in the construction of fuel tanks

Mohammad Nosratbakhsh, Soroush Maddah*, Yasser Rostamiyan
Department of Mechanical Engineering, Sari Branch, Islamic Azad University, Sari, Iran.

Received: December 2024 Accepted: February 2025

Extended Abstract

Introduction

Pressurized fuel tanks are critical components in many industrial and transportation systems, where safety, reliability, and structural integrity are of paramount importance. Since these tanks often store flammable fluids, any structural failure may result in catastrophic consequences. Therefore, advanced fluid, thermal, and structural analyses are essential to ensure safe operation under extreme pressure and temperature variations. In recent years, composite and sandwich-panel structures have attracted significant attention due to their high strength-to-weight ratio, corrosion resistance, thermal insulation capability, and cost-effectiveness compared to conventional metallic tanks.

Sandwich panels with lattice or truss cores offer additional advantages, such as enhanced stiffness, improved load distribution, and superior thermal performance. Although extensive research has been conducted on the thermal and mechanical behavior of sandwich panels in building and aerospace applications, their utilization in pressurized fuel tanks—particularly with lattice-core composite configurations—has not been sufficiently explored. Moreover, the interaction between phase-changing polyurethane foam, fluid pressure, and thermal gradients in such structures remains largely unexplored.

This study addresses these research gaps by proposing and analyzing a novel composite sandwich-panel fuel tank with a lattice core filled with polyurethane foam. A combined experimental and numerical framework is employed to investigate hydrostatic strength, fluid–structure interaction during foam phase change, and thermo-mechanical performance under external temperature gradients.

Methodology

A composite sandwich panel reinforced with Kevlar fibers and epoxy resin was manufactured using the Vacuum-Assisted Resin Transfer Molding (VARTM) process. The panel consisted of eight laminated layers with a $[90/0]_8$ stacking sequence and a diamond-shaped lattice core. Polyurethane foam was injected into the core to enhance structural stability and thermal insulation.

Material properties of Kevlar-reinforced polymer and polyurethane foam were experimentally characterized and implemented in numerical models. A full-scale sandwich composite tank was fabricated and subjected to hydrostatic pressure testing using a PT-150 testing device to determine its pressure resistance and leakage behavior.

Fluid dynamics simulations were conducted in ANSYS to model the phase change of polyurethane foam from liquid to solid. Transient analyses were performed to evaluate the evolution of foam volume fraction, temperature distribution, and pressure exerted on the sandwich panel walls during solidification. A refined tetrahedral mesh was used, and monitoring lines and planes were defined to extract quantitative results.

Thermo-mechanical finite element analyses were carried out in ABAQUS to assess the response of the sandwich tank under combined internal pressure, external pressure variations, and external thermal gradients. A coupled transient thermal–mechanical analysis was performed with appropriate boundary conditions, convection and radiation heat transfer, adhesive constraints between facesheets and core, and three-dimensional hexahedral elements.

Results and Discussion

Hydrostatic testing demonstrated that the composite sandwich tank successfully withstood internal pressures up to approximately **160 bar (16 MPa)** without rupture, confirming its high structural integrity. Leakage was observed at higher pressures, indicating that failure was not catastrophic but progressive and detectable.

CFD results showed that the polyurethane foam solidification process occurred gradually from the panel boundaries toward the core center. The liquid volume fraction decreased smoothly from unity to zero, while foam temperature dropped from **55 °C to 25 °C**. The pressure exerted by the foam on the sandwich panel walls remained negligible, with a maximum value of approximately **15 MPa**, indicating that foam injection and phase change do not induce harmful stresses and, in fact, contribute to structural reinforcement.
Thermo-mechanical analysis revealed that thermal stresses induced by external temperature gradients reached a maximum von Mises stress of approximately **26.7 MPa**, mainly concentrated in the upper and lower facesheets. The lattice core experienced significantly lower stress levels, confirming its effectiveness in load redistribution.
Temperature distribution results showed that internal tank temperature remained nearly constant at approximately **25 °C**, despite external temperature variations ranging from **−10 °C to 85 °C**, highlighting the excellent thermal insulation capability of the sandwich structure.
Stress analysis under internal pressure indicated a maximum von Mises stress of approximately **2.9 MPa**, well below material failure limits, with critical regions located near structural edges.

Conclusion

The results demonstrate that composite sandwich-panel fuel tanks with lattice cores and polyurethane foam filling offer a highly efficient, lightweight, and cost-effective alternative to conventional metallic tanks. The proposed structure exhibits excellent pressure resistance, thermal insulation, and mechanical performance under combined fluid, thermal, and pressure loading conditions.
Future research should focus on long-term durability, fatigue behavior, impact resistance, and fire performance of such tanks. Additionally, optimization of lattice-core geometry and foam properties could further enhance safety and performance. The findings of this study provide a strong foundation for the application of sandwich composite structures in next-generation pressurized fuel storage systems, particularly in automotive, aerospace, and energy sectors.

Key words: Sandwich panel, hydrostatic test, fluid analysis, thermal analysis, finite element method.

*corresponding author: S.Maddah@iausari.ac.ir

Cite this article as: Mohammad Nosratbakhsh, Soroush Maddah, Yasser Rostamiyan. Fabrication, modeling and fluid analysis of a composite sandwich panel with a lattice core for use in the construction of fuel tanks. **Journal of Energy Conversion**, **2025, 11(4), 65-85.**