Future of HDPE Liners for Lining Engineered Cavities for Bulk Hydrogen Storage

by GNA Editor

Introduction

As the world transitions from fossil fuels to a hydrogen-based economy, innovative storage solutions are becoming critical to support the anticipated rise in hydrogen production and use. High-density polyethylene (HDPE) exhibits significant potential as an impermeable liner material for lined engineered shafts (LES), which are increasingly being recognized as a viable option for large-scale hydrogen storage. These systems can scale from gigawatt-hours (GWh) to terawatt-hours (TWh) of storage capacity, playing a key role in stabilizing energy grids and supporting a net-zero energy future.

The Need for Large-Scale Hydrogen Storage

Hydrogen is poised to play a major role in a future energy system driven by 100% renewable energy sources. Large-scale hydrogen storage addresses two critical challenges:

1. **Energy Grid Stability:** By converting variable renewable electricity into hydrogen during periods of excess generation, storage systems provide a buffer to stabilize energy grids.
2. **Net-Zero Emissions:** Hydrogen serves as a clean energy carrier, supporting decarbonization across industries.

Lined engineered cavities (LECs), including LES, are among the most promising underground storage technologies for gaseous hydrogen. They enable high-pressure storage without being constrained by specific rock mass types, offering a cost-effective and flexible solution.

Advantages of Lined Engineered Shafts (LES)

Among the various configurations of LECs, LES are particularly advantageous due to their ability to reduce costs in softer rock formations, such as sedimentary layers. Their benefits include:

- **Cost Reduction:** Lower excavation and construction complexity make LES a more economical choice in softer rock masses.
- **Flexibility:** LES do not depend on specific geological conditions, making them suitable for a wide range of locations.

However, significant knowledge gaps remain regarding the long-term behaviour of LES under cyclical loading. These challenges underscore the need for further research and development to enhance the feasibility of LES for hydrogen storage.

HDPE as a Liner Material

HDPE has emerged as a leading candidate for LES linings due to its unique combination of properties:

1. **Corrosion Resistance:** HDPE offers superior resistance to corrosion, outperforming metals in harsh environments.
2. **Hydrogen Embrittlement Resistance:** Unlike metals, HDPE is highly resistant to hydrogen embrittlement, a critical factor in ensuring the durability of hydrogen storage systems.
3. **Economic Viability:** In terms of cost per unit volume, HDPE is the most economical choice, surpassing materials like stainless steel and polyamide. Its lower complexity and cost of welding further enhance its economic appeal.

While stainless steel offers unmatched mechanical strength and hydrogen sealing capabilities it is susceptible to hydrogen embrittlement and stress corrosion cracking (SCC) hence HDPE provides a cost-effective alternative with satisfactory performance for many applications.

Challenges and Research Directions

Despite its advantages, HDPE faces limitations in hydrogen sealing capabilities compared to materials like stainless steel. Additionally, the long-term behaviour of HDPE under high-pressure hydrogen storage conditions remains a subject of ongoing research. New electrical leak detection and leak location technologies for welded HDPE liners can mitigate the occurrence of leaks.

Future research should focus on:

1. **Numerical Modelling:** Developing robust numerical models to simulate the performance of HDPE liners under cyclical loading and high-pressure conditions.
2. **Material Advancements:** Enhancing the hydrogen sealing properties of HDPE through advanced manufacturing techniques and material formulations.
3. **Experimental Validation:** Conducting long-term experimental studies to validate the performance of HDPE-lined LES in real-world conditions.

Conclusions

HDPE holds strong potential as an impermeable liner material for LES in large-scale hydrogen storage systems. Its resistance to corrosion and hydrogen embrittlement, coupled with its economic advantages, positions HDPE as a leading material for future hydrogen storage applications. However, addressing its limitations through targeted research and development will be essential to fully realize its potential. By overcoming these challenges, HDPE-lined LES can play a pivotal role in the global transition to a hydrogen-based energy economy.

Further Reading:

Potential of HDPE Lined Engineered Cavities for Bulk Hydrogen Storage
HDPE exhibits strong potential as an impermeable liner material for lined engineered shafts (LES) for large-scale hydrogen storage at scales ranging from gigawatt-hours (GWh) to terawatt-hours (TWh)
https://www.sciencedirect.com/science/article/pii/S0360319924056866