Innovating pipeline integrity

Laurette Sapin Cuiret, 3X ENGINEERING, Monaco, discusses advanced composite technology for corrosion repair on pipelines.

Corrosion remains one of the most persistent and costly challenges in the oil, gas, and energy industries. From offshore production facilities to onshore tank farms, metallic structures are continuously exposed to aggressive environments that degrade their mechanical strength and operational reliability. Traditional repair techniques – such as welding, clamping, or component replacement – often require shutdowns, high costs and significant safety risks.

Over the past decades, composite repair technologies have emerged as a reliable, cost-effective, and sustainable alternative. These systems, based on high-performance fibres and epoxy resins, are designed to restore the integrity of pipelines suffering from metal loss, cracks or leaks, while minimising downtime and operational disruption.

This article explores the principles behind modern composite repair systems and illustrates their performance through two recent case studies: an offshore crude oil washing line reinforcement on FPSO in Africa, and an onshore pipeline restoration in the Middle East. Both projects demonstrate how the combination of engineering expertise, standardised procedures, and high-performance materials can ensure the long-term safety and functionality of critical assets.

The challenge of corrosion in industrial pipelines

Understanding corrosion mechanisms

Corrosion occurs when metallic materials react with their environment, leading to gradual material degradation. In oil and gas operations, this process is accelerated by factors such as water salinity, temperature variations, high pressure, and the presence of corrosive agents.

The consequences of unchecked corrosion are severe: wall thinning, pitting, cracking, and ultimately, through-wall leaks. These defects compromise pipeline integrity, increase the risk of environmental contamination and may lead to costly unplanned shutdowns.

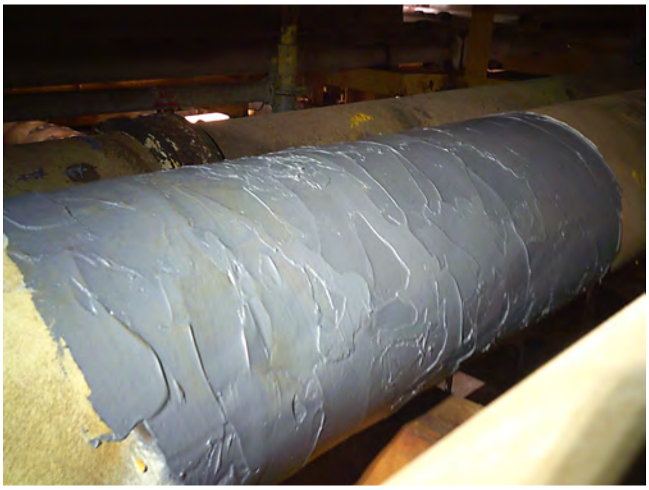

Figure 1. Case study 1: surface reconstruction with filler.

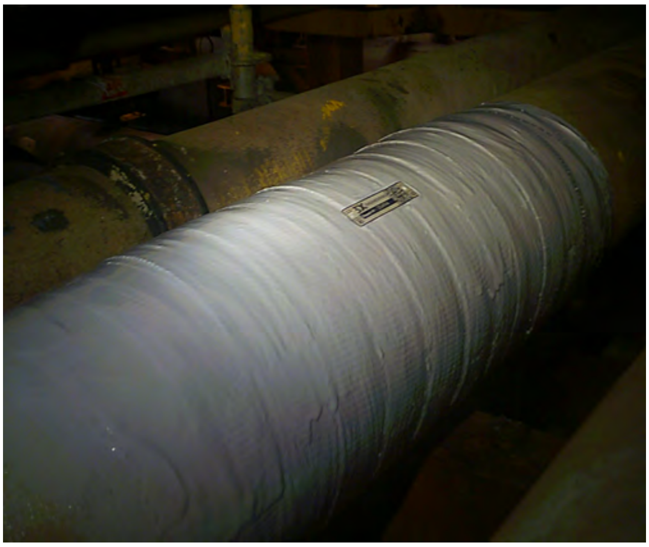

Figure 2. Case study 1: repair overview.

Limitations of conventional repair methods

Conventional methods like welded sleeves, clamps or full component replacements, though effective in certain situations, present major limitations:

- Operational disruption: welding often requires depressurising the line or stopping production.
- Safety concerns: hot work in hydrocarbon environments increases fire and explosion risks.
- Cost and logistics: offshore and remote operations make heavy equipment transport and on-site fabrication complex and expensive.
- Short-term performance: mechanical repairs may not resolve underlying corrosion mechanisms or provide durable protection.

These challenges have driven the industry toward non-metallic and composite-based solutions that can be applied on-site, even under challenging conditions.

Composite repair technology: a high-performance alternative

Principles of composite reinforcement

Composite repair systems typically consist of two main components:

- Fibre reinforcement: high-strength fibres such as Kevlar®, carbon, or glass, providing mechanical resistance.
- Polymeric resin matrix: an epoxy system that ensures adhesion, load transfer, and chemical resistance.

When applied over a damaged pipe section, the composite forms a structural laminate capable of restoring or exceeding the original design pressure. The repair is engineered to comply with standards such as ASME PCC-2 or ISO 24.817, ensuring mechanical performance and long-term reliability.

Advantages of composite systems

Composite technologies offer several key benefits:

- No hot work: repairs can be applied cold, eliminating fire hazards.
- Minimal or no downtime: many applications can be performed while the line remains in service.
- Versatility: suitable for various geometries (straight lines, elbows, tees, and flanges).
- Durability: properly engineered systems can last for over 20 years under harsh conditions.
- Lightweight and easy to install: ideal for offshore or challenging environments.

Case study 1: offshore crude oil line reinforcement on floating production, storage, and offloading (FPSO) unit – Africa, May 2025

Project overview

In May 2025, an 8 in. crude oil washing line on a FPSO unit presented multiple defects, including five corroded areas and four leaks. The line operated at a temperature of 60°C and a pressure of 16 bar, conditions that required an immediate, robust repair to prevent environmental risks and costly shutdowns.

A high-performance composite repair system was selected to reinforce the affected areas. The objective was to restore full mechanical integrity while maintaining safe production operations.

Scope of work

In compliance with ASME PCC-2 standard, the composite repair solution specified the use of Kevlar tape impregnated with bi-component epoxy resin. The procedure involved:

- Four layers of composite applied over areas affected by corrosion.
- 10 layers applied over through-wall defects.

To ensure adhesion, the surface was prepared using Bristle Blaster® machine to achieve cleanliness equivalent to St3/SA 2.5 and a surface roughness greater than 60 µm (Rz). Once prepared, the area was degreased with acetone and the composite reinforcement was applied through several key stages:

- Leak sealing: a specific metallic and filler device was installed to seal active leaks before wrapping.
- Surface reconstruction: a high-performance filler was used to rebuild the pipe geometry.
- Resin application: the first layer of epoxy resin ensured strong adhesion between the substrate and the composite wrap.
- Composite wrapping: Kevlar tape layers impregnated with resin were applied to provide structural reinforcement.
- Finalisation: a final resin coating sealed the repair and an identification plate was installed for traceability.

For long-term protection, an anti-UV topcoat was recommended to protect the repair from UV degradation.

Results

The intervention fully restored the mechanical integrity of the line. The repair successfully withstood operational pressure and temperature without leakage. By using an advanced composite solution, the operator avoided production interruption, reduced safety risks, and extended the pipeline's service life.

This project was part of a broader series of eight similar repairs completed on the FPSO, all of which were successfully executed, leaving the facility fully operational.

Case study 2: onshore tank farm pipeline rehabilitation (Middle East, April 2025)

Project overview

In April 2025, specialists were tasked with repairing a 24 in. pipeline and a 2 in. elbow within an onshore tank farm. The assets had suffered from internal corrosion, resulting in seven localised defects that compromised structural reliability. The client looked for a long-term solution that could be implemented rapidly and without major operational disruption.

The chosen composite repair system was designed to restore full mechanical performance in accordance with ISO 24.817 standards.

Figure 3. Case study 2: composite wrapping on progress.

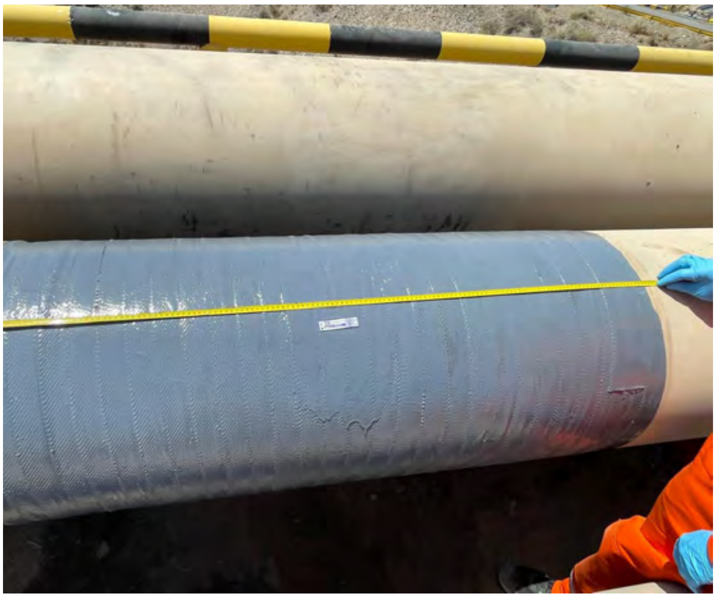

Figure 4. Case study 2: repair overview.

Scope of work

Surface preparation was carried out using sandblasting to achieve a surface roughness exceeding 60 µm (Rz), ensuring proper bonding between the steel substrate and the composite material.

After confirming hygrometric conditions, each defected area was cleaned, degreased with acetone, and reinforced using the following steps:

- Primer application: a high-performance epoxy resin layer was first applied to create a strong adhesion base.
- Composite wrapping: four layers of Kevlar tape impregnated with resin were wrapped around each defect. The total repair lengths varied by location:
  - 600 mm for one straight-line defect.
  - 1350 mm for a second straight-line defect.
  - 820 mm for the 2 in. elbow.
  - 600 mm each for the remaining four locations (straight line).
- Final coating: a final resin layer was applied to seal the system and ID plate was installed for traceability.

Results

Resin samples were collected during installation for quality control and post-repair hardness testing confirmed that the material achieved full curing and mechanical strength. The results demonstrated successful pipeline restoration.

To enhance durability, the client was advised to apply an anti-UV coating after a 72 h curing period. The repaired sections returned to normal operation without any reported issues, confirming the reliability of composite repair technology for internally corroded pipelines.

Engineering confidence through standardisation

Both projects highlight the versatility and efficiency of modern composite repair systems. Whether applied to external corrosion and leakage on an offshore FPSO or internal corrosion within a tank farm pipeline, these technologies provide engineers with reliable tools to manage asset integrity safely and economically.

The success of each intervention was supported by:

- Strict adherence to international repair standards (ASME PCC-2 and ISO 24.817), including type approval by certification bodies.
- High quality surface preparation, ensuring optimal adhesion.
- Controlled application procedures, including environmental monitoring and traceability, supported by trained and experienced application teams.
- Quality control testing, verifying resin curing and hardness.
- Support from a responsive technical team able to guide field operations when unexpected site conditions arise.
- Use of resin systems developed to be as versatile and tolerant as possible, ensuring robust performance even under non ideal conditions.

These principles demonstrate how advanced composite repair systems bridge the gap between engineering rigor and practical field execution, empowering operators to extend the service life of aging infrastructure without costly replacements.

Advantages in offshore and onshore applications

The two case studies emphasise that composite repair solutions are not limited by geography or environmental conditions. Key advantages include:

- Adaptability: effective for both external and internal corrosion, leaks and structural defects.
- Ease of application: allows installation in tight spaces, underwater or in potentially explosive environments.
- Predictable performance: repairs are engineered based on finite element analysis and validated testing.
- Sustainability: eliminates the need for heavy steel replacements, reducing carbon footprint and material waste.

By adopting such systems, operators enhance asset sustainability while aligning with global trends toward greener and more efficient maintenance technologies.

Sustainability for a greener world

Advancing pipeline corrosion repair technology plays a vital role in promoting sustainability and building a greener world. By extending the service life of existing pipelines, modern repair methods such as composite wrapping help reduce the need for new steel production and large-scale replacements, which are both energy-intensive and carbon-heavy processes. These innovative solutions minimise environmental disruption, lower greenhouse gas (GHG) emissions and conserve natural resources. Finally, sustainable pipeline repair technologies demonstrate how industrial innovation can align with environmental responsibility to create a cleaner and more resilient future.

Conclusion

The fight against corrosion is an enduring challenge for industrial operators worldwide. However, the emergence of advanced composite repair technologies has transformed the way companies maintain and extend the life of their critical assets.

As demonstrated by the offshore and onshore case studies, these systems deliver proven mechanical reinforcement, rapid installation, and long-term durability, all without the need for hot work or production shutdowns.

Thanks to ongoing innovation, compliance with global standards and proven field results, composite repair technology has become a key solution for modern asset integrity management, helping industrial pipelines stay safe, efficient and sustainable even in the most demanding environments.