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Common Composite Repair Misconceptions





Five Common Composite Repair Misconceptions

Composite repair products used in oil and gas pipeline rehabilitation and restoration applications have been available for close to 30 years. In that time, a wealth of misconceptions has evolved regarding these products, their principles and their performance.

When compared to conventional pipe repair options such as welded steel sleeves or clamped repair systems, composite repairs are often not given fair consideration. Some operators and asset owners in the oil and gas industry are apprehensive when it comes to using or expanding the use of composite repair products — not because of the performance of these products, but because of the limited amount of unbiased information that is available for them. The rare stories of some composite repairs not meeting expectations further compound the issue, but these are often due to improper product selection or product installation.

To help set the record straight, we'll look at five common composite repair misconceptions, where they originated, the reality of those misconceptions and why it is vitally important to understand the engineering behind these solutions as well as their capabilities and effectiveness in each unique repair.

During the past 30 years, a wealth of misconceptions have evolved regarding composite repair products, their principles and their performance.

1 | Any off-the-shelf product can address my simple repair

2 | Only certain composites can be inspected

3 | Composite products provide only a temporary repair solution

4 | Composites can't adequately repair crack-like features in pipe

5 | Fabric or laminate construction is a marketing ploy



#1

MISCONCEPTION:

Any off-the-shelf product can address my simple repair

There are plenty of manufacturers that would have operators believe their products are adequately manufactured to handle any repair based on their one-size-fits-all construction. In reality, these types of products can provide a good repair solution only in the right conditions, but even then, that doesn't necessarily make it the right or the best option. There are many variables when considering a composite repair, including operating pressures and temperatures, defect type and severity, pipe geometry and external or internal chemical presence. Considering all these variables, it is near impossible for a single, ready-made composite to work well in any situation.

"Pre-designed," ready-made repair products should only be used to address very specific situations. These situations and limitations should be clearly and plainly understood. However, keep in mind that the prevailing ASME PCC-2 and ISO 24817 standards state that each repair should be properly designed in accordance with the standards. On the other hand, manufacturers of a truly engineered composite repair product should be able to explain how the engineering of said product will address the specific problem being considered. Finding a product that is engineered to the exact specs of a given scenario will not only offer the optimum design required to provide a sufficient repair, but it can also reduce costs. Additionally, there are many other conditions, such as bending or combined loading, that the repair must address. This is more likely to be done if the repair is custom designed versus assuming an off-the-shelf product has pre-considered these loads.

Some manufacturers may pitch the low number of layers that comes standard with their composites as a key benefit; however, layer count is not necessarily as important as total repair thickness and how the system addresses certain stress loads such as bending. If a composite decision is made solely on the basis of its constant repair thickness (layer count) alone, the results could be costly. Having more material (constant repair thickness) than necessary will mean purchasers are paying for material they don't need. If the operator decides to err on the side of perceived expedience, depending on the product type and kit, the repair could consist of too thin a composite, resulting in a repair that could potentially fail. This scenario means a second repair is imminent and adds costs that could have been avoided with an initial proper solution.

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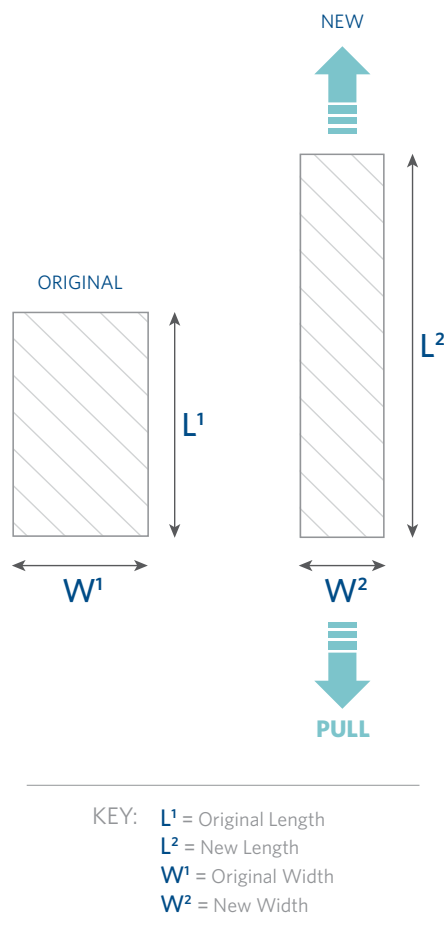
For example, a manufacturer might offer a standard fixed-layer composite for any given pipe size as a stocked repair product. If, in fact, the circumstances of a repair require more layers than provided to address the hoop stress, the only option is to use two fixed-layer composites, which creates layers of redundant composite, but that still may not address bending or axial loads.

Ask Your Manufacturer

Can your manufacturer explain the importance of **Poisson's Ratio** with regard to how the composite product will address your repair? If a manufacturer cannot demonstrate knowledge surrounding this crucial point of engineering, the company may not be able to provide an adequate and purposefully engineered repair.

Stress on a composite repair due to an increase in the internal pressures of the pipe will cause the composite repair itself to shrink axially. This could lead to an issue in adhesion if it is not properly considered.

POISSON'S RATIO DEMONSTRATED



Poisson's Ratio is a measure of shrinkage in one direction when being stretched in another; this is primarily measured in terms of strain relationships.



#2 MISCONCEPTION:

Only certain composites can be inspected

The topic of pipeline inspection can be cloudy for many asset owners. The lack of complete understanding is in part due to vague inspection standards and the fact that inspection contractors are really the only ones deeply involved in the process, thereby being the only group who has developed an education around the subject.

Although they don't have a hand in the physical inspection process, operators are the final decision-makers on product selection. Through manufacturer marketing, many have been conditioned to shop for composite repair products with one question in mind for manufacturers and suppliers:

"Are your composites inspectable?"

The universal answer — no matter the manufacturer — is, yes.

There are several means of non-destructive testing (NDT) that not only inspect and analyze defects within the walls of a pipe, but also the surrounding composite material, regardless of the manufacturer.

Tap Test: As far as composite testing goes, this is by far the least scientific, but still a great preliminary test to determine if further inspection is necessary. Using a metal object such as a quarter, an inspector can tap the quarter along the outside of the composite and use the sound of the tap to determine if a defect exists within the composite. A deadened "thud" or a sudden change in the sound of the tapping is a strong indication of an internal defect within the layers of composite wrap. There are more sophisticated methods and equipment available to better conduct this test and record results (Tap Hammer, RD3 and CATT).

Phased Array: This form of ultrasonic NDT uses several independently pulsing piezoelectric transducers that can be swept at a variety of angles to locate defects. This ultrasonic method can be used to detect defects within the pipe, voids between the pipe and the composite repair, and voids or delamination within the composite itself. The equipment transmits the results of the scan digitally, producing either a 2-D, top-down view known as a "C-scan," or a 2-D, side-on view known as a "B-scan."

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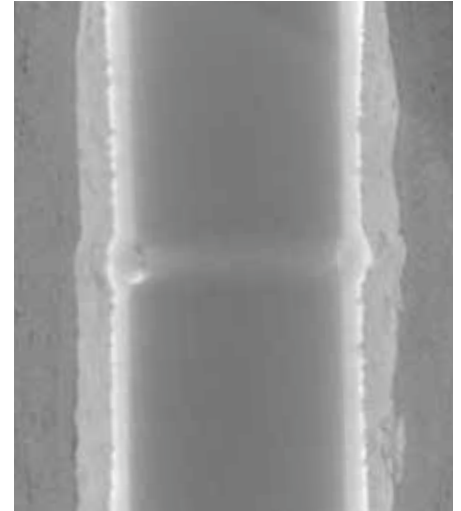
EMAT: Another form of ultrasonic NDT, EMAT inspects pipes and composites by producing electromagnetic waves that interact with the conductive materials found in some composite repairs. These materials give off their own electromagnetic waves. The combination of these uniquely produced electromagnetic waves creates sound waves that are used to locate damages and defects. EMAT is one of several guided wave techniques. Guided waves are different from conventional UT because guided waves utilize the structure itself to create waveforms that can inspect over longer distances.

Unlike in phased array testing, EMAT does not need to come into direct contact with the area being inspected. This feature allows it to be used from the outside of the pipe or as an inline testing method, which would prevent operators from having to dig up any assets to touch or inspect them. Detected defects are digitally transmitted and produced in a 2-D C-scan or 3-D image.

Pulsed Eddy Current: This NDT method, based upon Faraday's Law of Magnetic Induction, is an electromagnetic testing method that uses a transmitter to produce alternating currents that induce looping currents, or eddy currents, in nearby conductive materials — in this case the substrate. Existing defects interfere with the flow of the eddy currents and are presented in the form of a colored grid. Areas with greater wall loss will show up as a particular color corresponding to the severity of loss.

Digital Radiography: Also known as X-ray, this method uses penetrating radiation to inspect delamination and disbonding within the materials being tested. This method can find defects in both the composite and in the pipe wall. Requiring that a transmitter and a receiver be placed on the pipe across from each other, this option is primarily chosen for pipes that are already completely exposed. As this inspection method deals with the transmitting of gamma rays and X-rays (high energy, short wavelength radiation), safety is a primary priority.

Transmitted waves that have not been interrupted by defects within the pipe or composite material make their way to the receiver to form an image that gives an actual photographic representation of the insides of the pipe or composite. The 2-D images produced can be stitched together to form a 3-D image using computed tomography. The positioning of the void or defect within the pipe or composite can make determining the width or length difficult and will often require several images from different angles.



Source: PRCI presentation presented at a CRUG event.

Digital radiography inspection method.



Microwave: This method is used to detect defects such as delamination and disbonds in nonconductive materials. While not for use with carbon fiber composites, the process and equipment are simple, making for a quick inspection process.

Transmitted waves are reflected back when meeting a void or discontinuation in the material. These voids are identified as areas of delamination, disbonding or gouged composite and cause the microwaves to be reflected back to the inspection instrument at a different rate. In a 2-D color or grayscale C-scan (depending on user preference), inconsistencies in the reflected rays represent defects within the composite.

Thermography: By detecting the change in thermal activity within a material, thermography can find defects by creating a heat map of the surface of a stressed object. This method can find defects within the composite through the use of an infrared camera and equipment, which applies energy to the inspection area. As this energy encounters a void or discontinuity, it is dissipated as heat at a different rate than the rest of the material. The infrared camera is then able to detect these hot zones by recording the surface temperature of the composite and the defects.

This method is better suited for defects closer to surface level because the energy required for inspection increases as it progresses deeper into the composite. The thicker the composite, the more difficult it will be to identify deeper defects.

Some forms of inspection are more ideal choices for certain scenarios over others, but the important point to remember is that there will always be an inspection method available no matter the composite repair product in place. Some of the inspection technologies do incorporate several of the above methods to cross-verify the results.

The important question is not whether a composite can be inspected, but what do the results mean? This question leads directly into our third misconception.

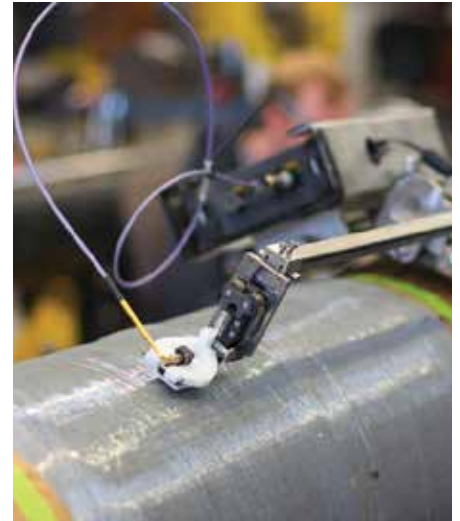


Photo courtesy of PETRONAS and Sonomatic Ltd.

Microwave inspection method.



#3 MISCONCEPTION:

Composite products provide only a temporary repair solution

The largest issues with this misconception is lack of definition when it comes to the words “temporary” and “permanent.” They tend to mean something different to each operator, manufacturer and auditor. With regards to composite repairs designed for one scenario or the other, a general definition may be given as:

Temporary repair: This repair will be installed for a specified, usually short, amount of time with specialized scheduled inspections or a planned service removal.

Permanent repair: This repair will be installed without requirements for specialized scheduled inspections other than routine scheduled inspections for the entire pipe.

In either case, a “permanent” repair is only viable for a composite repair system if the defect itself has been addressed and no further damage to the pipe or composite repair is anticipated. Therefore, all internal wall loss defects, external abrasion or extremely high fatigue scenarios will be treated as temporary, requiring either a planned removal or an ongoing inspection plan. Additionally, specific repair systems with known longevity issues, such as cracking in the composite or allowing further corrosion growth under the repair, may need to be monitored more closely and not be considered “permanent.”

If no growth is expected so that the current and end-of-life conditions are the same, a “permanent” composite repair becomes a viable option. Some of the additional items that need to be considered include composite creep and the cyclic fatigue life of the composite and the pipe.

Composites that are designed for long-term use need to consider creep-fatigue associated with the composite material and an estimated design life.



Source: PRCI presentation presented at a CRUG event.

Before and after 20" OD horizontal natural gas pipeline composite repair.



Composites that are designed for long-term use need to consider creep-fatigue associated with the composite material and an estimated design life. Creep occurs when a system undergoes continuous loading and the atomic structures in the material relax to a state of least energy. For most composites, this state is largely reached within the first year with nearly insignificant weakening occurring over the remainder of its life. The amount of creep experienced is directly proportional to the amount of load present.

However, the key point here is that long-term composite repairs need to have this strength reduction taken into consideration. In other words, do not use short-term test values for a design basis without having a significant safety factor built in.

Another key design life factor is cyclic fatigue. This can occur in either the substrate pipe or the composite repair itself. When adequately designed, a composite repair will usually only see stress states ranging from 5 - 20% of its ultimate stress state and can generally be assumed to have an indefinite cyclic fatigue life. It is important to note, however, if systems are being under-designed to be very thin (usually for cost advantages), cyclic fatigue may play a large role in the design life and should be questioned. Cyclic fatigue in pipes tends to be a very important factor for pipes with severe defects or any type of mechanical damage or crack-like features. A composite repair design in these situations needs to address not only the pipe's short-term rehabilitation, but also how it will address the pipe fatigue as well.

When the above concerns are addressed, there is a very real chance the composite repair and substrate pipe will perform and last well beyond what people consider "temporary" and more into the realm of "permanent." Years of field and third-party testing of composite repair products have shown that there are several options available that meet ASME and ISO engineering standards and are tested in accordance with ASTM and ISO. This testing shows that composites can withstand harsh elements, high pressure and the effects of long-time exposure in severe environments. Capable of providing repairs that can span decades, engineered composites can offer an extremely cost-effective solution.

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#4 MISCONCEPTION:

Composites can't adequately repair crack-like features in pipe

Often, an operator may interpret crack-like features in a pipe as damage that requires a costly repair by either replacing a section of pipe or introducing a welded or clamped sleeve in order to extend the life of the asset. The phrase "crack" is broad and doesn't help identify what type of crack-like feature or actual crack exists. To do so, the type of crack and the extent of the damage must be determined. Depending on the outcome of those answers, a composite repair may be an adequate solution to mitigating the damage and prolonging the life of the pipe.

One of the primary types of cracks is environmentally assisted cracking, and the most common form is stress corrosion cracking (SCC). SCC is categorized into two groups:

High pH SCC —

Crack colonies that are associated with coal tar-coated pipes (pH 9-10 at pipe surfaces) that occur throughout the U.S., Australia, Iran, Iraq, Italy, Pakistan and Saudi Arabia. The majority of these colonies occur axially, with very few instances of transverse cracks.

Near-Neutral SCC —

Crack colonies associated with tape- and asphalt-coated pipes (pH 5.5-7.5 at pipe surface), which are more likely to occur in Canada, Russia and the northern part of the U.S. About two-thirds of these incidents involve axial cracking. Those remaining are generally oriented transverse to the pipeline's axis.

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SCC occurs when a susceptible pipe is in an aggressive environment under high-sustained loads. When the coating fails and environmental factors lead to external corrosion, the sustained stress in the pipe causes the weakened pipe to initiate a crack. As more cracks continue to initiate in a colony, cracks begin to coalesce and form larger cracks that eventually lead to failure. Composite products are being looked into as an option for prolonging the life of the pipe by isolating the external corrosion and preventing further crack initiation and coalescence.

Another common concern among pipelines are seam-weld anomalies. These are often considered “crack-like” as they can be manufacturing flaws and are not technically undergoing crack propagation. However, as current inspection technologies cannot adequately differentiate between crack and crack-like, most manufacturing flaws are treated as cracks under a “worst-case” scenario. These types of flaws are categorized as cold-welds, lack of fusion or hook-cracks. While these manufacturing flaws may never lead to a through-wall crack failure, it is in the operator’s best long-term interest to always act conservatively.

However, until the proper research has been finished, current cracks and crack-like features can only be repaired for the long-term. In accordance to the ASME B31.4 standard, this is only appropriate if the crack has first been mechanically removed without penetrating more than **40 percent** of the wall thickness. This method of repair consists of first mechanically removing any pipe wall that has an external crack or crack-like feature. The composite repair material is then applied to structurally rehabilitate the pipe now suffering from only external wall loss, as well as inhibit future corrosion.

As it currently stands, composite repairs should only be considered a temporary repair for situations where the crack or crack-like feature cannot be removed without additional, focused testing. In some limited seam weld anomalies that contain crack-like features, a composite repair may be a viable option for preventing crack initiation. As a temporary repair, composites can bridge the gap until a more permanent solution can be installed. The hope with current test programs is to demonstrate that composites may be a viable long-term repair option for cracks or crack-like features under certain conditions.

As more cracks continue to initiate in a colony, cracks begin to coalesce and form larger cracks that eventually lead to failure.





#5 MISCONCEPTION:

Fabric or laminate construction is a marketing ploy

When considering composite repairs, maintenance engineers should pay close attention to a product's fabric or laminate construction. A product listing may reference uni-, bi-, tri- or quad-directional fabrics. These terms aren't just sales speak or marketing terms, but rather are important structural characteristics that can ensure the right composite is selected for a repair.

Uni-directional fiber-reinforced composite fabrics are designed just as they sound. Fibers are oriented and aligned in a single direction, making these fabrics extremely strong in that direction. Depending on the orientation of the composite when applied to a pipe, the composite will inherently neglect either the hoop or axial stress state of the pipe, making the repair extremely weak to any loads not parallel with the fiber construction. A uni-directional fabric can result in a repair that is unable to handle bending, thermal loading or multi-axial load conditions that are associated with pipeline dent and wrinkle bend repairs. The above limitations and weaknesses do apply to pre-cured systems as well because the fiber orientation neglects axial stresses.

Bi-directional fabrics are created in a **0°/90°** woven configuration, which can address the stress load bearing ratio of 2:1 to adequately support both the hoop and axial stresses if designed accordingly. The amount of support is determined by the ratio of fibers aligned in each direction. Typically, hoop stress will be predominately supported, but the fabric can be tailored to provide certain percentages of support without needing to sequence layers. Additionally, the thin composition of bi-directional fabrics makes them relatively flexible and easily formed to complex shapes while either wet or dry.

This particular composition is not without its faults. When exposed to torsional or shear forces along the 45° line, bi-directional fabrics are weak. Also, because of the space required to include fabric for supporting axial stresses, there is a reduced modulus and strength — generally making bi-directional fabrics slightly weaker than uni-directional fabrics in regard to only pure hoop stress. The woven composition of bi-directional fabric increases unused space between fibers, decreasing the overall strength compared to fabric in which the fibers are stacked and stitched together.





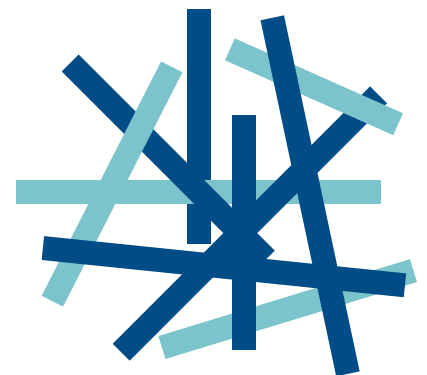
Tri-directional fabrics venture away from a woven design. They are typically engineered in a stacked fashion, with a prevalent strength in the hoop direction — typically with fabric aligned along the **0°, +45° and -45°** lines of the fabric.

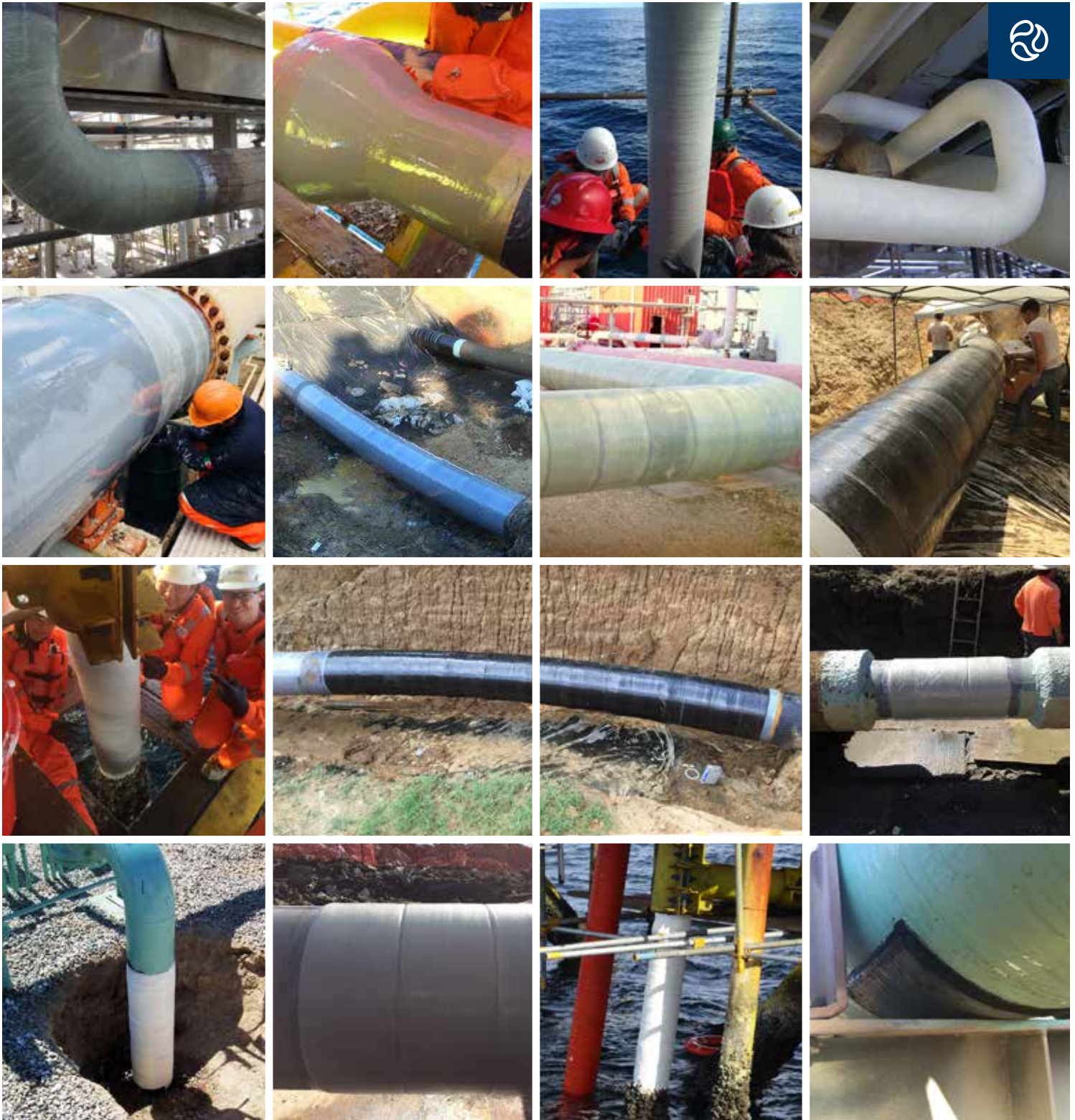
This configuration provides a much greater distribution of load-bearing capabilities. Because the fabric is stacked and stitched together, this sequence also minimizes space between fibers, making a tri-directional fabric great for leak repairs. Though slightly thicker and slightly less pliable than a bi-directional fabric, its tight fiber structure and workability make it the best option for conforming to irregular shapes while also addressing multi-directional stress loads.

If no fibers are placed directly along the 90° line, axial stress loads are distributed to all other non-perpendicular fibers. This composition gives tri-directional fabrics a reduced modulus and strength compared to uni-directional fabrics along any single direction; however, it provides a higher overall strength in all directions due to the total number of fibers.

Quad-directional fabrics are another stacked and stitched composite that include fibers typically placed along the **0°, +45°, -45° and 90°** directions, making this composite relatively strong in every direction. Acting mostly isotropic (like metal), this composition is ideal for leak repairs due to its strength and sequencing. Because it is thick and stiff in all directions, however, it is an extremely difficult composite to apply to complex shapes. While quad-directional fabrics have the highest average overall strength and modulus in stress, they actually have the lowest strength and modulus in any single direction. These fabrics are typically overkill when it comes to more simplistic repairs, which can add unnecessary costs.

Randomly oriented fabrics are not as common as the previously mentioned compositions but are yet another available repair product. These fabrics contain no directional preference, making them isotropic and very stable in the planar direction. They can also be easily formed around complex shapes. However, due to the lack of direction, this construction provides minimal strength — only about 30 percent, or less, of what can be achieved by uni-directional fabrics. Because of this, randomly oriented fabrics are typically used in low-stress applications where they can be utilized mostly as a preventative measure. Randomly oriented fabrics may be sequenced with uni-directional materials oriented in various lines of action to make up for the lack of support in other directions.





Have you considered an engineered composite product for your repairs recently?

What's keeping you from using this as a repair solution?

If you have objections, find out if they are rooted in truth.

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