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Introduction

Since their introduction as a viable method of pipe repair, composites have been rapidly gaining adoption for use in the repair and maintenance of piping systems. These composite repair systems generally consist of a filler material for reshaping the pipe surface, an adhesive primer to act as a coating and bonding agent, and lastly, the composite material itself to provide strength and rigidity back to the pipe system. Perhaps one of the key aspects of a composite material is its ability to be highly versatile. From small, 1-inch pipes to large flare lines, to drums and tanks, composite repairs can be designed for very specific scenarios using standard stock material. With the ability to change resins in order to address different temperatures and chemical compatibility needs, it comes as little surprise that composites are used across pipes and vessels carrying water, acidic chemicals, hydrocarbons, gas, and many other products.

One area where composite repairs have been seen to have a large benefit revolves around corrosion under insulation (CUI). CUI generally occurs when water gets into or under the insulation material due to weather, water-based cleaning, fire suppression systems, or any other number of ways. There are several different types of CUI including galvanic, alkaline, acidic, or chloride corrosion. In almost all cases, the key component is that water containing various chemicals ends up in direct contact with a susceptible pipe, and since insulation is not airtight, it creates an environment of high potential for aggressive corrosion to occur. Once damaged, the defect will continue to grow unless the pipe is segregated from the corrosive environment once more. In many cases, the damage that has already been inflicted can be detrimental to the service of the pipe and may need to be repaired.

Many articles and research papers exist that go into details regarding CUI causes, prevention, and inspection methodologies. However, most articles do not focus on restoration and assume that the only practical options are an immediate cut and replace or recoat for continued service or future replacement. However, a solution now exists that is being more commonly used, which involves the use of composite material to mitigate light CUI damage and/or repair and restore structural strength to the piping system.

Benefits of a Composite

First, a composite repair can be used as a preventative measure or early mitigation tool. In cases where the damage is non-existent or not severe, minimal layers of a composite system can provide multiple benefits. The primary benefit here is that the composite itself acts as a tough, impervious coating that protects the pipe from further environmental interaction. In many cases, the pipe has an existing coating or paint which can also be damaged by the issues causing the CUI, thus leading to further issues as it also begins to fail. Use of a composite to replace the damaged sections will ensure a robust solution that is not susceptible to the same types of damage.

Second, modern composite repairs have a large variability of resin and fabric options and can be designed accordingly with the design or operating conditions and limits in mind. There are highly engineered systems which are able to withstand continuous temperatures of up to 715°F (379°C) as well as a range of aggressive, harsh chemicals. Standard fabric widths and lengths allow the composite material to be installed around unique geometries as well, including elbows and tees with no off-site customization and only limited on-site customization for unique geometries.

Third, composites can also provide external protection from impact which may damage a general coating unseen under insulation and may also help to dampen severe vibration effects on the line. Many process pipes also experience heavy vibration which can be dampened with a composite repair to help extend the life of the asset and coating. Additionally, composites can be used on lines with heavy or frequent cycling to absorb stress resulting in lower strains in the base pipe per cycle. The combination of impact, vibration, and cyclic protection goes a long way in ensuring that the area under the composite repair will not be exposed to the environment during long-term operations.

For CUI defects that have led to additional damage, such as widespread or deep corrosion pits or stress corrosion cracking (SCC), composite repairs can be utilized to protect the pipe, mitigate future damage, and restore the lost strength or capacity of the pipe. Utilizing several design methodologies, composite repairs can be designed to restore hoop or axial strength occurring due to wall loss. These same composite repair systems are often used in high-pressure pipeline repairs where they are designed as "permanent" repairs or often have a design life of 20 to 50 years with wall loss defects up to 80% deep. This same methodology and expectations on design life could also be applied to the type of external corrosion experienced with CUI and give plant operators a significantly increased operating life of the pipe network under protection of the composite.

Composite repairs accomplish this reinforcement through load sharing between the pipe and the composite effectively lowering the stress-strain load in the pipe expanding the anticipated service life of the unit. The degree of existing damage, the operating conditions, and the desired future service time are primary considerations when determining the required composite repair thickness to ensure sufficient structural reinforcement in the pipe.

Additionally, when a defect goes through-wall composite repairs are often used to contain the leak until the pipe can be replaced at a convenient time. When addressing a leak, another important consideration comes into play, namely that of chemical resistance. Several different composite systems exist that focus on different chemical resistances and allow varied use on lines ranging from water lines and single chemical lines to flare lines with a large mixture of chemicals at higher temperatures.

More complex defects such as SCC on a stainless-steel pipe may also be addressed with composite repairs. For SCC to occur, the pipe needs to be a susceptible material, under sufficient stress, and in a susceptible environment; all conditions which can be exacerbated due to the CUI environment. A composite repair can protect the exposed or damaged pipe from the susceptible environment even through an impact event which, by itself, eliminates future SCC occurrences. While the outside of the composite repair may be damaged in a severe impact event, it absorbs and distributes the load, minimizing damage to the bond line and substrate pipe. In fact, to qualify for leak containment in ASME PCC-2, impact tests are performed to ensure this attribute. However, if the line is operating at a reduced pressure during installation, the composite repair also reduces the stress seen in the pipe potentially eliminating the high-stress environment. With two of the three requirements removed through a simple composite installation, SCC defects can be repaired with relative ease.

When compared to other common repair options for severe defects, a composite repair provides additional benefits seen under CUI circumstances. Composites are often used in various industries, including aerospace and marine, for their high strength-to-weight ratio and this benefit extends to pipes as well. With a specific designed thickness to address a defect, composite repair materials can provide the lightest-weight repair solution to the affected pipe area. Additionally, composites will provide a form-fitting repair that allows for easy application of insulation overtop even around sharp elbows, flanges, tees, nozzles, or reducers. Lastly, by being a non-metallic repair option, there is no concern of the future trapped moisture in the insulation causing corrosion to the repair. This of course relies heavily on a clean and prepared pipe surface which ensures adequate bonding; as well as relying upon correct installation.

Case Studies

Reviewing a real-life application of a composite repair on CUI can demonstrate many of the benefits at once. In this case, a 6-inch, schedule 40 pipe carrying liquid styrene suffered extensive CUI over 38 distinct areas on the line. These areas included elbows, girth welds, vents, and drains with corrosion up to 50% of the pipe wall (**Figure 1**). Due to the complexity and quantity of CUI, the asset owner consulted a major composite repair provider for a solution. After assessing each defect area and the asset owner's allowable repair systems, an epoxy fiberglass composite repair system was used. Based on the defect severity and asset owner's desire, a 20-year design was engineered necessitating a seven-layer composite system.

The repair system was installed with no shutdown or major disruption to operations. The pipe was properly prepared using a bristle blaster to remove rust, mill scale, and the previous damaged coating. Afterwards the surface was washed with acetone to remove

Figure 1. CUI was discovered in 38 areas on elbows, girth welds, vents, and drains on a 6-inch diameter pipeline carrying liquid styrene.

any contamination and then subsequently dried to remove any residual solvent and humidity. An appropriate amount of filler material was then applied to fill in the corrosion spots and restore a circular profile to the pipe. The primer layer was then applied followed by the seven-layer epoxy fiberglass composite repair system to provide the long-term structural integrity and corrosion protection required by the owner operator. Once completed, the repaired area could then be re-insulated with no further worry of corrosion in the repaired areas.

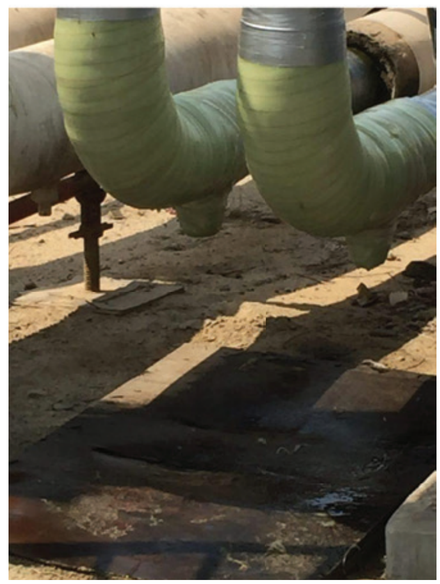

Figure 2. Using a composite repair solution allowed installers to restore the facility to safe operations with minimal equipment and manpower and without disrupting operations.

In another project which showcases the versatility of composites for CUI mitigation and repair, a refinery chose to wrap approximately 380 linear feet (116 linear meters) of a 20" diameter suction line. A section of insulation was removed due to an anomaly found on inspection data, which prompted the stripping of insulation from the length of the pipe. As the insulation removal continued, heavy-to-severe exfoliation type CUI was discovered along the entire top half of the piping. Scraping revealed lake-type pits throughout, up to 0.250" deep, with areas of pitting up to 0.300" deep. UT thickness readings with a pencil-type probe revealed a remaining wall thickness as low as 0.047" in some locations, which prompted the refinery to look into a structural option to repair and remediate.

Since the line would need to remain in service, the asset owner resolved that a composite repair system was the ideal solution to maintain the line's integrity and protect against future corrosion

Figure 3. Insulation being stripped from length of 20” pipe

Figure 4. Close-up of heavy CUI damage

until it could be replaced during the next scheduled shutdown. With the assistance of a field support crew, contractors were able to quickly apply the composite materials with minimal manpower and no need for heavy equipment or hot work. The composite repair system installation was performed without incident and with no disruption of service, which enabled the asset owner to continue operations safely and efficiently.

Summary

Corrosion under insulation remains a serious issue in today’s piping world, but composite repairs may provide a great solution that bridges the gap between a simple re-coat and immediate cut-out or heavy-duty steel clamps. With their ability to be customized for minor or severe defects, low or high temperatures, or mundane or aggressive chemical services, composite repairs can address almost any need attributed to the effects of CUI without significantly adding weight or complexity for future operations. Although often seen as a temporary repair when used for leaking-case defects, composites can certainly provide a long-term repair option, especially if the defect is caught prior to going through-wall or becoming too severe.

Finally, it is important to remember that these composite repair systems do not need to be specifically formulated or manufactured to handle CUI. The benefits discussed are natural results of using existing composite repair systems that are likely already being deployed for other defect repairs in your facility. This allows asset owners to utilize existing composite approvals and stocked material to address CUI quickly and cost-effectively. The keys are to make sure the system will handle the environment while considering surface preparation, temperatures, chemicals, stresses, and that it is designed properly to do the job! ■

For more information on this subject or the author, please email us at inquiries@inspectioneering.com.

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Casey Whalen graduated with Bachelor of Science and Master of Science degrees in Aerospace Engineering and has been serving the oil and gas industry since 2012 through composite design engineering. As an active member of the ASME PCC-2 subcommittee, he has been working on expanding the use and acceptance of composite repairs with programs such as crack repairs in transmission pipelines. He currently sits as the Global Engineering Manager for CSNRI enhancing our engineering capabilities across the world.

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