THE REPAIR OPTION

Sam Cheok Whai, Alstern Group, Singapore, discusses composite repair systems and FRP pipe repairs developed to meet the demands of the oil and gas industry.

Composite repair systems remain a constant repair option for industries requiring the repair and rehabilitation of piping systems. Various techniques and testing methods, which have the ability to handle different critical conditions onsite, are being developed in order to meet the demands of the industry. Composite materials are recognised as a reliable and effective means of repairing corrosion damage, mitigating corrosion concerns and keeping critical piping systems in production.

Figure 1. Alstern team providing repair of FRP pipe.

Fundamentals of composite repair systems

While operating pressure is not always high, the chemicals and the elevated temperatures of some piping processes accelerate internal and external corrosion. In most cases, wall loss is quite severe; in many cases, it has become a safety hazard or is leaking. Complete wall loss and pinhole leaking is a regular occurrence within many facilities. In order to repair these types of defects, a composite system must meet the minimum requirements and perform at the expected level under extreme conditions. Whilst numerous composites are available on the market, there are few that have the testing and capability to perform at the elevated temperatures that may be experienced.

Types of composite repair systems

Layered systems and wet lay-up systems are general types of repair systems used for composite repair. SealXpert™ Wrap Seal PLUS™ Fibreglass Wrap employs a fibreglass system that provides strength and stiffness, a resin matrix that is used to transfer the load between fibres. The wet lay-up system involves pre-impregnated fibreglass cloth that is activated in the flied by water. An advantage of this system is that the cure state tends to be monolithic and can be used to cover a range of geometries, including tees, elbows, bends and even valves. When designing a repair system using composite materials, engineers must consider both strength and stiffness. From a composite standpoint, strength relates to the tensile strength of a particular system, while stiffness relates to elastic modulus. For most conventional repair systems, there is a direct correlation. For example, a uniaxial Eglass system will typically have an elastic modulus order of 5 x 106 psi to 6 x 106 psi. The strain to failure for E-glass is on the order of 2%. Therefore, one can conclude that typical failure stresses for uniaxial E-glass systems are between 100 ksi and 120 ksi.

Carbon fibres are stiffer (i.e., higher modulus); however, their strain to failure is approximately half of Eglass. It is worth noting that elastic modulus is related primarily to fibre type, orientation and volume fraction. In a layered system, one must consider the contribution of the adhesive. Based on questions posed to the authors, it is clear that there is some confusion. Unless a perfect bond exists between layers, inefficiencies are introduced in terms of the actual elastic modulus. For example, it is possible for a composite to have an elastic modulus at the lamina level of 5 x 106 psi; however, with the introduction of adhesives the elastic modulus can be reduced to approximately half this value, or 2.5 x 106 psi.

Recognising the importance of stiffness, development of a composite repair system must consider the elastic modulus. This is especially important when considering the level of reinforcement provided to the carrier pipe, which is typically steel. Consider a non-reinforced steel pipe that has a diameter to wall thickness ratio greater than 20. Barlow's equation, which is based on shell theory, is used to calculate circumferential (hoop) stress in the pipe (Table 1).

When a pipe is repaired using a composite material, the stress in the carrier pipe is reduced in proportion to the reinforcement provided by the composite material. At the interface, circumferential strains in the pipe and composite reinforcement materials are equal. Using compatibility and first principles, the modified circumferential stresses in the carrier pipe is calculated using the following relation (Table 2).

Table 1. σ hoop = PR/T	
P	internal pressure (psi)
R	pipe radius (in.)
T	wall thickness (in.)
σ	hoop stress in pipe (psi)

Table 2. σ hoop = PR/ [tp (1+Ectc/Eptp)]	
tp	pipe wall thickness (in.)
Ep	pipe elastic modulus (psi)
tc	composite material thickness (in.)
Ec	composite material elastic modulus (psi)
σ	hoop stress in pipe (psi)

Factors affecting FRP pipes

Fibreglass reinforced polymer (FRP) is one kind of composite material. It is made of a polymer matrix reinforced with fibres. It is cheaper, easier and faster to manufacture than

Figure 2. FRP pipe with serious longitudinal crack.

Figure 3. Composite repair on FRP pipe.

steel or cast aluminium and provides excellent corrosion resistance for programmes that demand simplification of parts in production and operation, weight saving, precision engineering and finite tolerance. However, FRP pipe is susceptible to thermal shock that is caused by the rapid rate of change and frangible, which may result in cracking of the corrosion barrier and significant stress on the entire pipeline system. As FRP pipes are brittle and have little tolerance for vibrations, they are susceptive to cracks (which is a common issue onboard FPSOs).

Figure 4. Composite repair completed by Alstern Technologies.

Figure 5. Repairing FRP pipe.

Composite repair on FRP pipe

A 52 in. FRP sweater cooling pipe, buried underground with an operating pressure and temperature of 150 psi and 30 ˚C respectively, was connected to three plants (Polypropylene, Aromatics and Refinery). There was a 10 in. longitudinal crack along the top section of the FRP pipe, which was propagating longer each day. However, it could not be shut down for repair.

Using composite repair, the repair was completed successfully without the operating system having to be shut down. SealXpert metal repair putty and Wrap Seal PLUS fibreglass repair tape was applied.

SealXpert stainless steel pipe clip was applied to tighten the FRP so the crack did not further propagate. It can be used for temporary or permanent repair for securing, mounting, strapping, clamping and positioning. In addition, it can be applied to all conventional clamping jobs and can be cut into any required size.

After the pipe crack was prevented from further deterioration, SealXpert metal repair putty was applied around the pipe circumference. It was allowed to cure for one hour so that it could be dried/hardened to the pipe surface. There are a number of SealXpert repair putties that suit different applications. They are high performance metal-filled epoxies and are the best choice for repairing holes, cracks and defects. The repair putty can be drilled, tapped, machined or painted. In addition, they are quick-curing and cost-effective in returning equipment back to service.

Finally, a suitable size Wrap Seal PLUS fibreglass repair tape was applied for pipe reinforcement. It employs a fibreglass system that provides strength and stiffness, a resin matrix that is used to transfer load between fibres. The wet lay-up system involves pre-impregnated fibreglass cloth that is activated in the flied by water. It is durable, strong and permanent to restore pipes to original strength.

Other applications

Leak repair

A 6 in. FRP water injection pipeline for an onshore drilling station, with operating pressure 400 psi and temperature 70 ˚C, was thinning to 40% wall thickness due to erosion of sand sediments against internal of pipe elbow. In addition, machinery vibration caused a crack to develop at the pipe elbow.

Alstern Technologies applied SealXpert repair putty and Seal Stic™ epoxy to stop the leak and reinforce the pipeline. Lastly, Wrap Seal PLUS fibreglass tape was used to reinforce the pipe wall thickness and successfully completed the project under safe conditions.

Corrosion repair

An FPSO in West Africa was facing severe corrosion issues at the carbon steel seawater cooling pipeline. FRP pipes have been used to replace these carbon steel pipes. However, FRP pipes are brittle and are susceptive to cracks as they have little tolerance for vibrations, which is a common issue onboard FPSOs. Therefore, SealXpert products were applied onto the FRP pipeline to provide reinforcement and increase its tolerance to vibrations.

Wrap Seal PLUS resin and activator was applied onto the pipe surfaces and socket joints. Upon curing, Wrap Seal PLUS fibreglass repair tape was wrapped around the pipe and socket joints to provide reinforcement.

Figure 6. New FRP pipes spools after reinforcement with SealXpert products.

Conclusion

Composite repair systems remain almost a constant repair option for industries requiring repair and rehabilitation of piping systems. Various techniques and testing for composite repair systems, which can handle different critical conditions onsite, are being developed in order to meet the demands of the industry. Consequently, it is believed that composite repair will become more and more important in the future.