COMPOSITES - CASE STUDIES OF PIPELINE REPAIR APPLICATIONS

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ABSTRACT

Composite repairs have been utilised within the transmission pipeline industry for over the past 20 years for the permanent repair and reinforcement of sections of the pipe wall which have been weakened due to corrosion.

Most internationally recognised repair codes such as ASME B31.4 and B31.8 accept the use of composites for this repair function.

Most oil and gas pipeline operators are familiar with composites and the health, safety, technical and commercial benefits they provide.

The purpose of this paper is to introduce new areas of repair applications where composites can be used and to provide case studies for these particular repair functions.

What is a composite repair and how does it work?

A general definition of a composite is a synergistic combination of two or more materials. More specifically, composites comprise high strength reinforcement in fibrous form, incorporated into and bonded together by a matrix, usually a thermosetting polymer. The most common strength fibrous component used is glass.

Composite repairs for pipeline defects work by sharing the hoop load in the pipe wall, although the steel will still yield the yielding rate will be controlled by the externally applied composite sleeve so that the maximum allowable operating pressure (MAOP) can be safely maintained.

A typical and effective composite repair is a three component system consisting of:

- The composite structure.
- An adhesive system used to bond the composite to the pipe and to each successive layer of the applied wrap.
- A high compressive strength load transferring compound applied into the defect. (Figure 1) shows a Clock Spring composite repair.

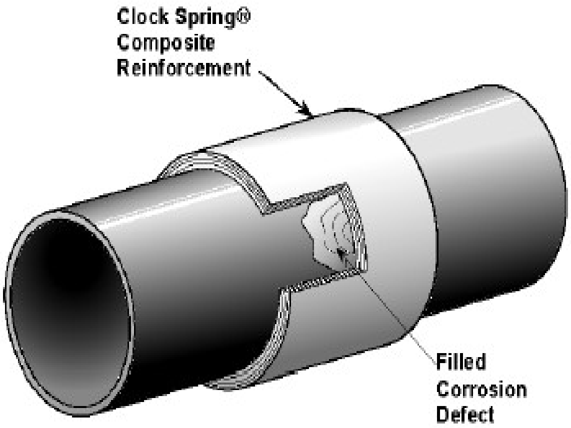

Figure 1

Repair Applications and Case Studies

1. **External corrosion**.

A corrosion cell can find its way to a pipeline not only through the ground but also by air. A refinery in the USA had major external corrosion (up to 80% metal loss) on a 12" (300 mm) pipeline caused by airborne drift from a cooling tower (Figure 2). The total length of the effected area was in excess of nine hundred feet (270 metres).

Figure 2

A conventional solution to this problem would have incurred serious challenges such as: hot work permits, re-scheduling of products and many other environmental and safety concerns due to the close proximity of process equipment and other product pipelines.

A composite reinforcement provided a logical alternative. Use of a composite repair eliminates the need for hot work, shut down of the pipeline, environmental exposure and the repairs could be installed within the tight clearances available.

In total 903 composite repairs were installed at a rate of 75 to 100 units per day using three x two man installation crews.

The repairs included straight pipe lengths as well as 45º and 90º degree elbows (Figures 3 and 4).

Figure 3

Figure 4

The composite repair not only provides proven permanent reinforcement but also corrosion protection to the pipeline from the effects of the continual airborne drift and vapour from the cooling towers.

As a proven 50 year permanent repair the extended life of this pipeline now exceeds the expected life of the refinery.

2. Bend and High Temperature Repair.

Due to platform subsidence it was found that as a number of risers were slowly sinking significant corrosion had developed above the original corrosion protection of the initial splash zone.

Replacement of the riser sections was considered but would have incurred two major problems, one a shut down of the platform and substantial production loss and secondly lengthy deliveries of the replacement section as the effected areas were on 3-D bend sections (Figure 5).

Figure 5

Composite repairs were considered but introduced three areas of concern:

(i) These are hot oil risers operating at up to 70ºC.

(ii) Access and personnel safety considerations.

(iii) Encapsulating of the complete bend section.

A composite repair was engineered to accommodate all these problems:

(i) Adhesive, filler and resin matrix chemicals were used that can withstand constant operational temperatures of up to 84ºC.

(ii) The repair composite is lightweight and easily handled allowing installation to be made using two operators and abseil techniques without the need for heavy lifting or specialised installation equipment. The installations were performed in the Summer and at the time of the lowest astronomical tide.

(iii) The composite reinforcement laminate sections were engineered and cut into bands to suit the bend radius. An outer layer of composite was then installed to completely encapsulate the first layer (Figure 6).

Figure 6

The repairs on each riser were completed within 3 days from start to finish with the riser remaining in operation for the duration of the installation process.

Another significant advantage of this repair was the elimination of all environmental concerns which can occur with the potential of hydrocarbon exposure to the environment when risers are removed from service.

3. Mechanical Damage.

During routine excavation of a water line the excavator accidentally hit a neighbouring 20" (500 mm) main gas line situated on the outskirts of Dubai in the U.A.E.

The excavator had "caught" the pipeline in three locations causing three significant gouges.

As the pipeline is the main supply to a local power station it was critical the pipeline remained in operation, it was mid Summer with temperatures in excess of 50°C and a peak period for electricity supply.

A large number of studies have been conducted concerning the suitability of composites for the permanent repair of mechanical damage and third party interference. The results of these studies have shown that composite repairs are acceptable providing the following steps are taken:

– The scrape or gouge is ground to a smooth contour to remove all stress concentrators. The maximum safe depth of grinding is 40% of the wall thickness.

- The damaged area is inspected to verify that any cracks have been removed by grinding.

- The residual indentation is filled with a hardenable filler for load transfer under the composite sleeve.

Figure 7 shows the pipeline after the gouges have been dressed and inspected. A composite sleeve is shown prior to being installed.

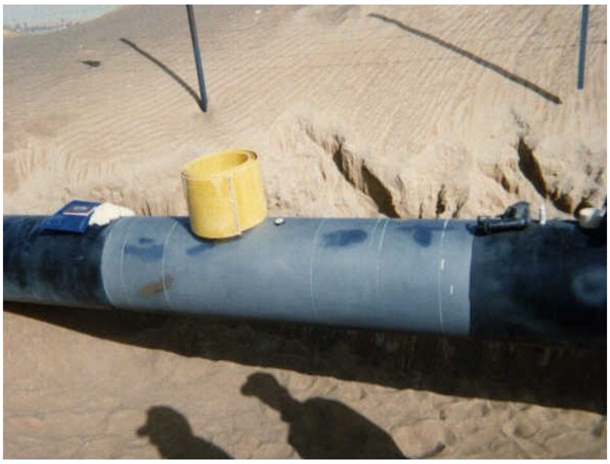

Figure 7

The three repairs were completed within 1½ hours (Figure 8) with the pipeline remaining in operation and the electricity supply to Dubai maintained.

Figure 8

4. Leak Repairs.

El-Segundo - California, a 24" (600 mm) crude oil, tanker offload pipeline used to supply a major tank farm was found to be leaking in several locations.

When operating the pipeline pressure is 22 Bar (300 psi). Access either side of the pipeline was a maximum of 6" (150 mm). No hot work was possible and the surface preparation could only be made using a power brush system.

In addition the repairs had to be made within 24 hours to allow an urgent tanker delivery to be offloaded.

Composites have undergone a large amount of laboratory and in-field testing for leak repair applications.

For a leak repair to take place it is a requirement for health and safety reasons to remove the pressure from the pipeline.

Once done the residual leak can be plugged (Figures 9 and 10) and the pipe surface cleaned.

Figure 9

Figure 10

To seal the plug a metal polymer paste (MPP) is applied and clamped in place and allowed to cure (Figure 11). Once the MPP has cured (20 - 30 minutes) the composite can be installed.

Figure 11

The application of the composite helps to remove additional hoop stress from the leak repair, can reinforce associated corrosion and protects the overall repair from external interference (Figure 12).

Figure 12

Test data on up to 1" diameter (25 mm) defects operating at pressures of up to 80 Bar (1100 psi) have provided extrapolated repair life data of in excess of 20 years.

Compared to traditional leak repair clamps, composites:

- eliminate the need for seals;
- can easily accommodate variations in the pipe outer diameter;

- are lightweight and easy to install;
- are available for immediate delivery.

In El-Segundo a total of 7 repairs were completed within 4 hours and the crude shipment offloaded on time (Figures 13 and 14).

Figure 13

Figure 14

5. Girth Weld Defects.

An MFL intelligent pig survey of a 20" (500 mm) gas pipeline in Poland located a series of anomalies associated with a large number of girth welds.

Further inspection of the girth welds identified the defects as being associated with the weld and included anomalies such as: lack of side wall fusion, porosity, pipe wall misalignment.

Within the USA and Eastern Europe a number of test programs were instigated to confirm the suitability of composite repairs for this application.

Tests were conducted on a number of pipe sections removed from operating gas lines where defects had been located in the girth welds which were of a serious nature to preclude continual operation of the pipelines at their MAOP.

Figure 15 shows the results of a pressure test on an un-repaired girth weld section.

Figure 15

Composite repairs were installed on the other available test pieces and subjected to a series of fatigue and pressure tests.

In all instances failure of the pipe occurred outside of the repair area (Figure 16) in the main wall of the pipe and at pressures significantly higher than the pipeline MAOP.

Figure 16

Following the results of this test work composite repairs have now been used in considerable numbers for girth weld reinforcement in areas such as Eastern Europe and the Former Soviet Union (Figure 17).

Figure 17

Again the composite repair provides many: safety, time and commercial advantages by eliminating either cut outs of the defect girth weld or installation of long length epoxy shell repairs which have typically been used for this application.

CONCLUSION

Composite repairs are a proven and accepted high pressure pipeline repair technology. Within Clock Spring to date we have completed over 100,000 repairs in over 62 countries worldwide.

Defects found in pipelines can be permanently repaired by using composite technology more safely, quickly and economically than any alternative technique.

The areas for application of composite repairs are expanding and now include:

- external and internal defects
- bend repairs
- weld repairs
- mechanical damage and third party interference
- pipe supports
- mill defects
- high temperatures
- sub-zero temperatures
- structural reinforcement
- crack arrestors
- open water repairs.

Composites are not the solution to all problems. However significant amounts of time and resources are still being applied to test and research programs to provide proven solutions for new repair applications. These will in turn provide the worldwide pipeline community with the correct answers and operational security required.