

Systems for Repair and Rehabilitation of Corroded Oil & Gas Pipelines



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Steel pipelines are the most effective and safest way for the transporting of oil and gas over long distances. It is normally formed by connecting spools of pipes, bends and joints by welding. According to a database published by the United State of America’s Central Intelligence Agency, there are over one million kilometres of pipelines laid around the world to transport oil and natural gas (1), and new pipelines are expected to be installed in the near future.

Damage caused by third parties, material and construction defects, natural forces and corrosion have been identified as significant factors contributing to failure of pipelines worldwide (2-5). Damaged pipelines are a common and serious problem which involves considerable cost and inconvenience to the industry and to the public (6).

A recent explosion in an underground pipeline network in Kaohsiung, Taiwan, killed 27 people and injured 286. Initial investigations showed that the cause was probably due to a leak in an underground pipeline owned by a local chemical producer which used a 4-inch propene pipeline (7).

Therefore, inspection and repair technology are critical for the prevention of accidents, safety in operations and the extension of running time of the long-distance pipelines (8). In order to extend the safety and durability of such pipelines, methods to repair damages have been developed.

At present, the inspection technology for both internal and external corrosion is quite reliable, using various techniques such as magnetic flux leakage (MFL) detection, pipeline current mapping (PCM) and ultrasonic detection (9). When defects are detected, the operators will assess the pipeline condition and

decide if repair is necessary. If it is, there are a variety of repair systems available. But before the repair work, the operators have to check a list of parameters including pipeline operating characteristics, geometry and materials so that the best choice of repair systems can be made (10). This is very important to ensure that repair system selected is safe, cost effective and reliable.

CONVENTIONAL STEEL SLEEVE/CLAMP REPAIR SYSTEM

Most underground pipeline systems consist of metal pipes due to their high strength, relative simplicity of joints and low cost. Conventionally, the most reliable repair system is to remove the entire damaged pipe and replace it with a new one. Or one can remove just the damaged section and cover it with a welded steel patch. Alternatively, the repair can also be done by installing a full-encirclement steel sleeve or steel clamp. These conventional repair systems incorporate external steel sleeves that are either bolted or welded to the outside surface of the pipes (Figure 1).

If a section of the pipe is severely damaged, the operator can remove the entire spool of pipe or cut out the damaged section. A new spool/section will then be connected to

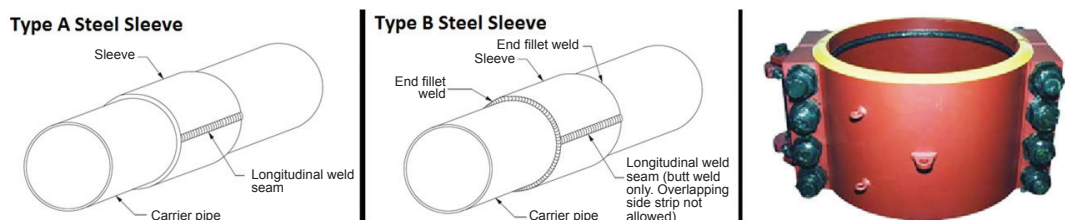


Figure 1: Full-encirclement steel sleeve (left and middle) and steel repair clamp (right).

the pipeline. The use of full-encirclement steel sleeve was developed in the early 1970s.

There are two basic types of full-encirclement steel sleeves. The Type A sleeve functions as reinforcement for the defective area by welding two pieces of steel sleeves longitudinally. The Type B sleeve is welded in the same manner as the Type A sleeve but, in addition, the ends of the sleeve are welded circumferentially to the carrier pipe. This type of repair is capable of repairing leaking defects or defects that may leak in future because the ends are fillet welded to the carrier pipe.

Besides welded sleeves, steel clamp repair is another alternative for repairing corroded steel pipes. Instead of welding, the sleeves are joined by mechanical fastening. The operation principle of the previously mentioned repair systems has proved to be effective by restraining the corroded section from bulging, hence the reinforcement. The long-term performance of steel repair systems is a great advantage which contributes to the relevance of this system until now.

There are several shortcomings in the repair systems mentioned. For example, these methods are generally suitable for straight pipe sections but not for joints or bends. Besides, welding or clamping of pipelines is bulky, costly and time consuming especially if the pipelines are underground (11). In most cases, heavy machinery is required to perform this cumbersome job. Furthermore, welding involves hot work that poses a potential risk of explosion.

So, researchers started looking for alternative repair systems that were relatively lightweight, easily applicable and be an effective repair solution.

FIBRE-REINFORCED COMPOSITE REPAIR SYSTEM

The use of fibre-reinforced composite materials to repair damaged pipelines started in the late 1980s. Since then, numerous institutions and companies have conducted their own R&D to develop commercial composite repair products. The trend is likely to accelerate.

The acceptance of composite based materials as an alternative to conventional repair materials, is indicated through the recent development of several codes and standards, including ASME PCC-2 (12) and ISO/TS 24817 (13). Both standards recognise composites as a legitimate repair material. To date, repair systems using fibre-reinforced composites can be categorised as pre-cured layered, flexible wet lay-up, pre-impregnated and split-sleeve systems. Although the products made by different companies and research institutes have varied performances, the composite material repair system will mainly include three parts:

1. High strength glass fibre or carbon fibre reinforcing materials;
2. Adhesive materials with high curing speed and high performance;
3. High compressed strength material for pipeline defects filling that conveys the load (14).

The pre-cured layered system involves bonding of pre-cured composite materials that are held together with an adhesive applied in the field. The repair using these systems is generally

limited to straight sections of pipe. Figure 2 (a) shows basic components of a commercially available pre-cured layered system, Clock Spring® repair system: (1) composite sleeve, (2) interlayer adhesive, and (3) infill material. The infill material is used to fill the damaged area to create a smooth surface. A composite sleeve will then be wrapped around the repair segment. An adhesive that serves as a bonding agent, is applied in every single layer of the composite sleeves.

When the infill material and adhesive are cured, the repair is considered done. Flexible wet lay-up utilises resin matrix that is usually uncured during application but forms a stiff shell after curing. Finally, a composite cloth will be used to wrap around the repaired area to strengthen the loading capacity as shown in Figure 2 (b). Since it is flexible, it can be used to repair joints or bends.

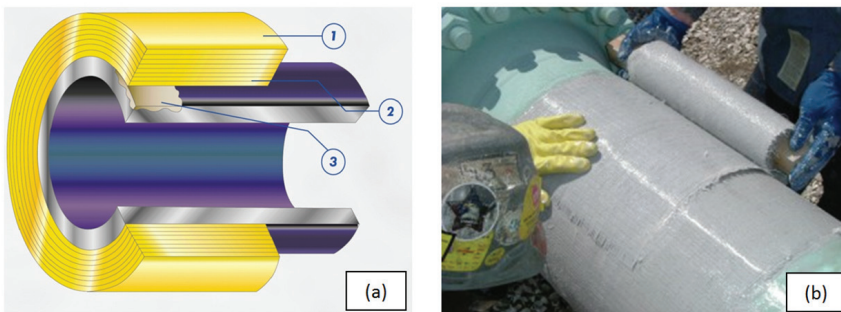


Figure 2: Clock Spring® (a) and Armor Plate® Pipe Wrap (b) composite repair system.

Figure 3 is an example of a pre-impregnated split-sleeve repair system. ProAssure™ Wrap Extreme in Figure 3 (a) was developed by a team of researchers from Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Petronas. The fibre is pre-impregnated with resin and stored in a specific environment (normally sub-zero degree Celsius) prior to repair. After repair, the composite will undergo in-situ curing and finally form a stiff shell.

Figure 3 (b) is the world’s first pipeline repair clamp to be made of the advanced composite material, ProAssure™ Clamp, as claimed by the manufacturer. The repair concept is similar to that of steel repair clamp. In case of material loss, either by corrosion or gouging, infill is used to ensure a smooth bed for the composite clamp. This also can be an effective leak containment solution for repairing defects that may cause pipeline leaking due to future deterioration such as corrosion and erosion.

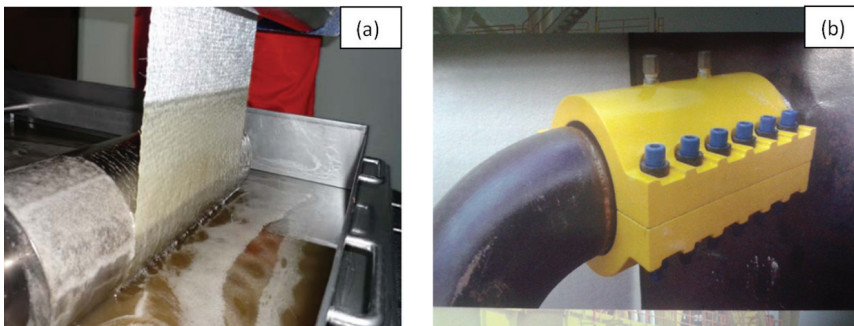


Figure 3: Clock Spring® (a) and Armor Plate® Pipe Wrap (b) composite repair system.

Benefits associated with composite repair systems include short length of time needed to complete a repair, uninterrupted product transmission in the piping system while the repair is made and eliminating the possibility of explosion since no welding or cutting of the pipeline is required.

Industry analysis shows that composite repair systems are, on average, 73% cheaper than completely replacing the damaged section of the steel pipe and 24% cheaper than welded steel sleeve repairs (15). Despite these

advantages however, long-term performance is a main concern for composite repair system. In response to that, an extensive research programme sponsored by Pipeline Research Council International, Inc. and 12 composite manufacturers from around the world was conducted to better understand the long-term performance of composite repair systems (16).

CONCLUSION

This article provides an insight into widely-used systems for repairing corroded oil and gas pipelines. In general, these can be categorised as conventional steel sleeve repair system and composite repair system. Both systems have advantages and limitations, so pipeline operators need to carefully evaluate the problem to determine which repair system is most appropriate for used. These include (but are not limited to) type of defects (leaking or non-leaking), operation constraints (allow for operation shutdown or not), permission for hot work, location of defect and future concern (future deterioration). For example, if hot work is not permitted, the welded repair system is not an option. On the other hand, if further corrosion is not a concern and the section to be repaired is a straight pipe, a steel sleeve/clamp may be sufficient to do the job due to its proven long-term performance. This is important to ensure pipelines can be operated safely within the designated operation lifespan. ■

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