COMPLEX MATERIALS

Rhys James, Lead Corrosion & Materials Engineer, Wood Group Kenny, Australia, discusses the challenges and solutions associated with the use of CRA clad and lined pipe.

As a result of the global demand for energy, current oil and gas projects are trending towards deeper water and harsher operating conditions. Given these conditions, an increased focus on pipeline design, installation and commissioning is required to ensure delivery of a successful project and ongoing integrity of pipeline operations, which are often designed for 30 years or more and then extended beyond this. These considerations have seen a rapid growth in the specification of corrosion resistant alloy (CRA) clad and lined pipe for hydrocarbon trunklines. In particular, large diameter, longitudinally welded pipe is being used more extensively.

Figure 1. CRA clad and lined pipes require enhanced preservation measures relative to carbon steel pipes.

The main advantage of this type of pipe is that oil and gas fields that are too corrosive to be handled by carbon steel pipes alone can be developed without the expense of using solid CRA pipe and without the need for costly chemical inhibition add-ons, which are often required for carbon steel pipelines. Higher strength outer carbon steel pipes that do not require manufacture to meet sour service requirements may be utilised. This would allow significantly reduced wall thicknesses relative to a plain carbon steel pipeline, which may need a large corrosion allowance to provide assurance of pressure containment over the project design life. For gas and mixed-phase lines where a temperature drop from one end of the line to the other would cause condensation and top of the line corrosion, CRA clad and lined pipe offers a reliable solution. Inspection frequency may be reduced and the risk of repairs can be minimised over a long design life.

The crossover from carbon steel pipe to CRA clad or lined pipe appears relatively straightforward when considered from afar: the same design practices, similar procurement codes, and installation and inspection methods are utilised. The only obvious difference between the two is the incorporation of a thin layer (typically 3 mm) of CRA material covering the inside of the carbon steel pipe. In reality, the use of CRA clad and lined pipe offers some challenges relative to plain carbon steel pipe use. These challenges require careful consideration to ensure the best solutions can be found and full advantage gained from the selection of CRA clad and lined pipes throughout the project lifecycle.

Figure 2. Allseas pipelay vessel *Audacia* with elevated stinger prior to commencing pipelay.

Figure 3. Inspection of concrete and insulation coated CRA clad joints at the coating yard for internal preservation and residual magnetism.

Manufacturing methods

For a start, pipe manufacturing methods vary somewhat for clad and lined pipe relative to plain carbon steel pipes. In the case of clad pipes, clad plates need to be formed to use as feedstock for the pipe forming process. This is done by sandwiching two layers of CRA material within carbon steel slabs, sealing the edges of the sandwich plates, evacuating any air between the layers and rolling at elevated temperatures. The diffusion of atoms between the different layers ensures a metallurgical bond is achieved over the entire surface of the plate and a clad plate is formed. A separating compound is used between the CRA layers to ensure bonding between these two layers does not occur. In this way, two clad plates are made per rolling operation. Lined pipe requires a CRA inner pipe to be made and then inserted into a carbon steel outer pipe and expanded before weld overlaying the end portions of the pipe.

The usual method for forming larger diameter (typically above 12 - 14 in.) and heavy wall thickness (approximately above 16 mm) clad and lined pipes is the press-brake method, also referred to as the 'JCO' process, where a single forming blade presses the plate against an anvil to form first one side of the pipe (the J shape), then the other side of the pipe (giving a C shape), before finally bringing the two sides together and welding the two edges together to form the O. This process is generally more flexible in terms of handling different material thicknesses and pipe diameters without significant outlay for size-specific tooling. For this reason, it is more suitable for the scale and quantities of clad pipe manufacture compared to the faster and more capital intensive 'UOE' forming process, which is commonly most economical for large-scale carbon steel line pipe orders. In this case, the plate is formed into a 'U' shape by means of a specifically sized die and press, before a second press forms the 'O' shape. After welding the edges together, the pipe is then hydraulically expanded, hence the 'E' for expansion. Seamless carbon steel pipes can also be used as the outer pipe for lined pipe manufacture, but typically only below diameters of 16 in. Clad pipes can also be formed by weld overlaying CRA material onto a seamless carbon steel pipe, but this is not a process that would be used to manufacture extended lengths of pipeline.

An artisan approach vs mass production

The differences in economies of scale are one reason for the manufacturing differences between CRA clad and lined pipe and carbon steel pipes, but CRA clad and lined pipe production also lends itself to a more bespoke, artisan approach due to the intrinsic need to take more care. Material needs to be handled more carefully; the cost of scrapping a joint is much higher, with a typical 18 in. alloy 625 clad joint of pipe costing as much as a luxury family car, several times more than what a carbon steel pipe might cost. This in turn results in a limited choice of suppliers of CRA clad/lined pipes.

This may simplify the tendering process in terms of numbers of potential bidders, but is another sign that such pipes are not in the same mass-produced realm as carbon steel pipes. Long lead times are common, which can be exacerbated if the quantities required are small or a particularly exotic cladding material is specified, which may pose a challenge if additional material is required quickly. Once this is understood it is clear that the increased focus and attention lavished on these pipes provides an end product that has been crafted and honed to a greater extent than a typical carbon steel pipe. Of course, this also comes at significant additional cost. As the introduction of a CRA layer introduces further complexity to the installation process, there may be areas that require further attention from an engineering and procurement perspective.

Clad and lined pipes produced through the 'JCO' or 'UOE' process require a longitudinal weld seam to join the pipe edges together. This has been an area where pipe diameter tolerances are hard to accurately control. Due to the thin layer of CRA material and the need to maintain this corrosion resistant barrier when installing the pipeline, fine dimensional control, especially of the diameter at the pipe ends is very important to ensure the fit up of each pipe end. A good fit up means that the CRA layer of each pipe can be aligned and welded satisfactorily during pipeline installation operations. Not only is this important technically, but ensuring good dimensional control of pipe ends ensures the correct fit up can be achieved in less time, which increases the efficiency of welding operations.

Measurement, installation and design methods

Understanding the measurement methods to be used by the pipe mill when applying the specified tolerances is important to ensure the final delivered product meets the expectations of the purchaser and installation contractor. This is increasingly important as pipe diameters increase, which typically means larger allowable dimensional tolerances. Measurement of pipe ends using full circumference scanning technology is becoming more commonplace to ensure pipes meet dimensional tolerances, but design codes do not yet require the universal application of such technology when validating dimensions. As a result, less precise methods are still acceptable. Knowing the limitations of any measurement methods up front is important to avoid any surprises when it comes to installing the pipeline.

Aside from welding fit-up, the addition of a thin internal CRA layer can cause further challenges from an installation and design perspective. Weld consumables must be both capable of resisting corrosion by the produced fluids and at least match the carbon steel pipe mechanical properties, often over a significant temperature range. Exceeding these properties may not always be possible, especially where X65 or higher grade carbon steel has been specified, which has further effects on engineering criticality assessments (ECA) and fatigue analysis, ultimately increasing the quality requirements of the installation process by reducing the maximum acceptable flaw size during pipeline welding operations.

Figure 4. Internal view of CRA lined pipe. The machined weld overlay at the pipe end and the weld preparation show the thin lip of CRA material that needs to be carefully aligned with the next pipe.

Figure 5. Dimensional control of CRA clad and lined pipes is crucial to allow efficient welding operations.

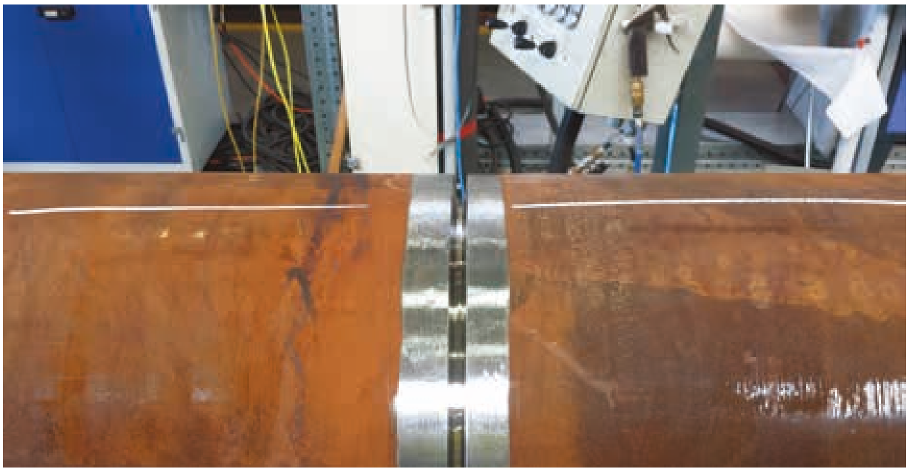

Figure 6. Precise alignment of pipe ends is required before welding operations can begin.

Figure 7. Stowage of suitable preserved CRA lined joints within the pipe transportation vessel hold.

There are also more subtle differences such as the behaviour of the weld pool: CRA consumables can exhibit a pronounced 'flow' up the sidewall of the weld preparation at the edge of the weld pool. A carbon steel consumable typically has a much flatter weld pool profile, which welders are more used to dealing with.

Buckling design needs to be looked at more carefully where lined pipe is used, as unlike metallurgically bonded clad pipes, the CRA liner is only held to the outer pipe by expanding the CRA liner within the outer pipe and sealing the annulus with welds at either end. This liner pipe will wrinkle and ultimately fail inside the outer pipe if sufficient bending strain is applied. The propensity for the liner to wrinkle is significantly diminished once the pipeline is pressurised, therefore liner wrinkling becomes more of a concern as pipeline diameter increases and as the carbon steel thicknesses increase relative to the liner thickness.

Pipeline preservation, storage and handling

In addition to installation and manufacturing concerns, focus is required on pipeline preservation, storage and handling, especially during pipeline coating operations. During the coating process pipes typically will be handled many times and are stored externally on berms, often in a dusty environment. That dust usually has a high iron ore content from high density concrete weight coating operations and iron ore contamination can lead to staining and iron contamination issues on the CRA surface. Acceptable housekeeping standards and preservation methods for carbon steel pipes fall short for CRA pipes, which are susceptible to contamination from iron pick up and water ingress. Most contamination is easily removed without significant damage to the CRA layer, though it does require time-consuming additional handling and cleaning of the pipes if sufficient attention is not paid to the handling, storage and transportation of pipes. Stainless steel is often a misnomer!

In order to minimise costs, it is usual to specify the least corrosion-resistant alloy that will suit expected conditions. This usually means that, where possible, austenitic stainless steel grades such as 316L are specified. This has the advantage of being relatively inexpensive and more readily available compared to the exotic nickel-based super alloys. Under certain conditions, 316L is susceptible to attack by seawater, therefore significant care and attention needs to be given to the risk of seawater ingress into the line during installation, through commissioning and operation. This risk can be mitigated by specifying a length of a hundred metres or so of pipe, clad in a more exotic and corrosion resistant material such as Inconel 625, to ensure that 316L material does not come into contact with untreated seawater. This approach is only successful when the pipeline has already been flooded with treated seawater or has some other means of restricting raw seawater to the very ends of the pipe. A gradual leak into a pipe as it is being laid is likely disastrous for any CRA material prone to pitting attack by seawater. Full testing and qualification of any valving associated with pipeline installation is therefore essential.

Conclusion

The use of CRA clad and lined pipe has a significant advantage over carbon steel pipelines when it comes to dealing with significantly sour, hot or acidic well conditions. Indeed, aside from solid CRA pipes, they may be the only option. The increased cost of procuring and installing this type of pipe relative to carbon steel is not the only consideration and care and attention needs to be given to the additional complexities that using this kind of material brings.