COATINGS ON A Quest

Pratheep Rajan, Canusa-CPS, Canada, examines developments in robust field-applied coatings for directionally drilled pipelines.

Horizontal directional drilling (HDD) or directional boring has become an increasingly popular trenchless method for installing buried gas and oil pipelines over the past few decades. When trenching and excavating is not an option due to the presence of various obstacles such as roads, railway tracks, steep slopes and watercourses, directional boring is the preferred and most trusted method for the installation of buried pipelines. Depending on the pipeline requirements, directionally drilled pipelines can range from smaller diameter pipelines to larger outside diameter (typically up to 56 in. OD) pipelines, and based on the obstacle, the length of the directionally drilled pipeline can also vary up to 2 km. During pipeline construction, the majority of the pipeline will be laid using an open-trench method, and only a small portion of the pipeline will be directionally drilled.

Typically, in the oil and gas industry, pipelines are constructed using carbon steel pipes that are factory-coated with 3-layer polyethylene (3LPE), 3-layer polypropylene (3LPP), or fusion-bonded epoxy (FBE) with abrasion resistant overcoat (ARO). These mainline coatings provide integrity to the pipeline by preventing corrosion and allowing the pipeline to last for the required service time, which is usually over 20 years.

Protecting the cutback

In recent decades, 3LPE and 3LPP coated pipelines have become well recognised choices for oil and gas pipelines. Three-layer coatings consist of fusion-bonded epoxy as the primary layer for maximum corrosion protection, a polyethylene (PE) or polypropylene (PP) topcoat for maximum mechanical protection and resistance to moisture absorption, as epoxies tend to absorb moisture more readily, and a tie-in PE or PP copolymer layer to provide maximum adhesion between the primary epoxy layer and the topcoat. The factory-applied coatings are applied onto the steel pipe leaving an exposed area (i.e. cutback) on both ends, which allows for the pipes to be welded together in the field (the coating would be burnt off by the welding process otherwise). The exposed steel area must also be protected with similar materials to the factory-applied coating to ensure consistent coating performance and thickness over the entire length of the pipeline. The coating used in this area is typically referred to as a field joint coating.

Factory-applied anti-corrosion coatings are designed and selected based on specific parameters such as operating temperature of the pipeline, pipe diameter, mechanical forces associated with the pipeline laying method, mechanical forces associated with pipeline operation, external pressure, flexibility and required operating life. Similarly, the field joint coatings must also follow the same or similar anti-corrosion coating design criteria as the factory-applied coating.

Field joint coatings designed to withstand the HDD process

Typical field joint coatings are comprised of a liquid, or fusion bonded, epoxy layer applied on the steel, a PE or PP outer layer for mechanical protection and a tie-in PE or PP copolymer layer to provide maximum adhesion between the primary epoxy layer and the topcoat. This system must also overlap and bond to the factory-applied coating on both sides to ensure consistent protection from moisture ingress along the entire length of the pipeline. Since the joint coatings are applied in the field, they must be designed while taking into consideration additional factors such as the local ambient conditions and terrain, impact on the application process, mainline coating type and thickness and contractor capabilities (equipment, personnel, etc.).

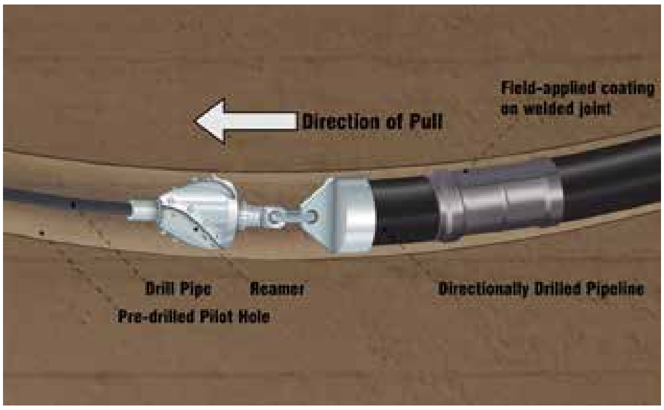

Figure 1. *Pipeline being directionally drilled under an obstacle.*

Figure 2. *Canusa-CPS DDX™ Directional Drilling field joint coating system passing through rollers prior to entrance into the bore.*

Given that the protective coatings used for directionally drilled sections of a pipeline must be able to withstand the pull-through forces associated with the HDD operation, additional focus should be given to these sections. Although an appropriately sized reamer is used to increase the overall diameter of the pilot hole initially drilled to create the drill path, and drill fluid is typically used to lubricate the bore hole, factory-applied coatings and field-applied coatings can be severely damaged during the HDD process. Depending on the soil type and the HDD process, various forces can act on the pipeline coating putting the protective coatings at risk of being damaged. Immediate HDD forces induced by the pull-through operation can be gouging, abrasion, extreme shear, impact and penetration. These forces created by the pipeline coming into contact with rollers during moving of the pipeline and with gravel, cobbles and boulders within the bore can severely damage the protective coatings during pull-through. In addition to these immediate short-term forces, the protective coatings can also wear out over time due to soil stress and pipe movements.

Since HDD pipelines are not easily accessible for future coating repairs, effective long-term soil stress resistance is therefore also extremely critical. For effective long-term protection, the protective coatings must be able to withstand soil stresses, thermal cycling and ageing, moisture ingress and penetration. Although the aforementioned anti-abrasion properties contribute to the overall performance of the protective coatings, critical anti-corrosion properties such as resistance to peel, shear strength, resistance to water absorption and cathodic disbondment must also be given equal importance, to ensure that the coating actually resists corrosion over the operating life of the pipeline.

These material properties can be easily tested in accordance with international test methods using internal test facilities or accredited third-party test laboratories. It is highly advisable to select coatings that meet international standards that clearly identify the requirements of protective anti-corrosion coatings. To identify the appropriate protective coating for field joints on HDD pipelines, various test methods and standards can be used in conjunction to narrow down the coating choices that will provide the required anti-corrosion and anti-abrasion performance.

Narrowing down the choice

The following properties will play an important role in the performance quality of the selected protective coating, regardless of whether it will be factory-applied or field-applied on the joints:

Gouging

Gouging of the protective coating can occur when sharp objects are extending into the borehole during a pipeline pull-through operation. If the protective coatings are not capable of withstanding resistance to surface gouges, it can easily compromise the integrity of the pipeline by exposing the underlying steel. Gouges not extending all the way to the steel can propagate to the steel in the long-term as other forces act on the coating over time. One commonly used test standard for gouge resistance testing is CSA Z245.21 by the Canadian Standards Association. The gouge resistance testing is completed by gouging a protective coating specimen that is travelling at a constant speed with a smooth carbide tip. The specimen's average coating thickness on the gouged area is compared to the average coating thickness prior to being gouged. Test parameters will need to be agreed on, based on the type of coating to be tested.

Abrasion

Abrasion resistance testing is conducted in order to assess the coating's ability to withstand the abrasion forces that can occur when the pipe comes in contact with the borehole wall during a directional drill. These forces are also exerted on the coating by the continual soil stresses and pipe movement that occur during the course of the pipeline service time. A common method for measuring surface abrasion resistance of a coating is the ASTM D4060 standard, although there are other accepted international test methods. According to the ASTM method, the test specimen is prepared using the protective coating and is rotated at a constant speed under abrasive wheels. After the specified number of abrasion cycles is complete, the loss of weight of the specimen is noted.

Shearing

Shear resistance testing is completed on the adhesive layer, which provides adhesion between the pipe substrate and the outer layer of the protective coating. When the field joint coating is applied, it does not just cover the exposed steel at the cutback, but also overlaps the factory-applied coating at the ends of the cutback. As a result, the field joint coating is extended off the smooth pipe surface. Shear forces will be exerted in the opposite direction of the pull in rigid soil types. The adhesive layer used in the coating must be able to withstand such shear forces during the pull-through operation as well as during the service time of the pipeline where it will be exposed to shear forces caused by continuous soil stress. Both EN 12068 and ISO 21809-3 outline the test method for conducting shear testing. A test specimen is prepared by melting the protective coating's adhesive layer between two steel plates. Once the adhesive recrystallises, it creates a bond at the area where the plates are overlapped. Using a tensile machine, a tensile force is applied parallel to the bond area at a specified constant speed. The amount of force required to shear the adhesive over a unit of area determines the adhesive layer's shear strength. Typically, shear testing is conducted at

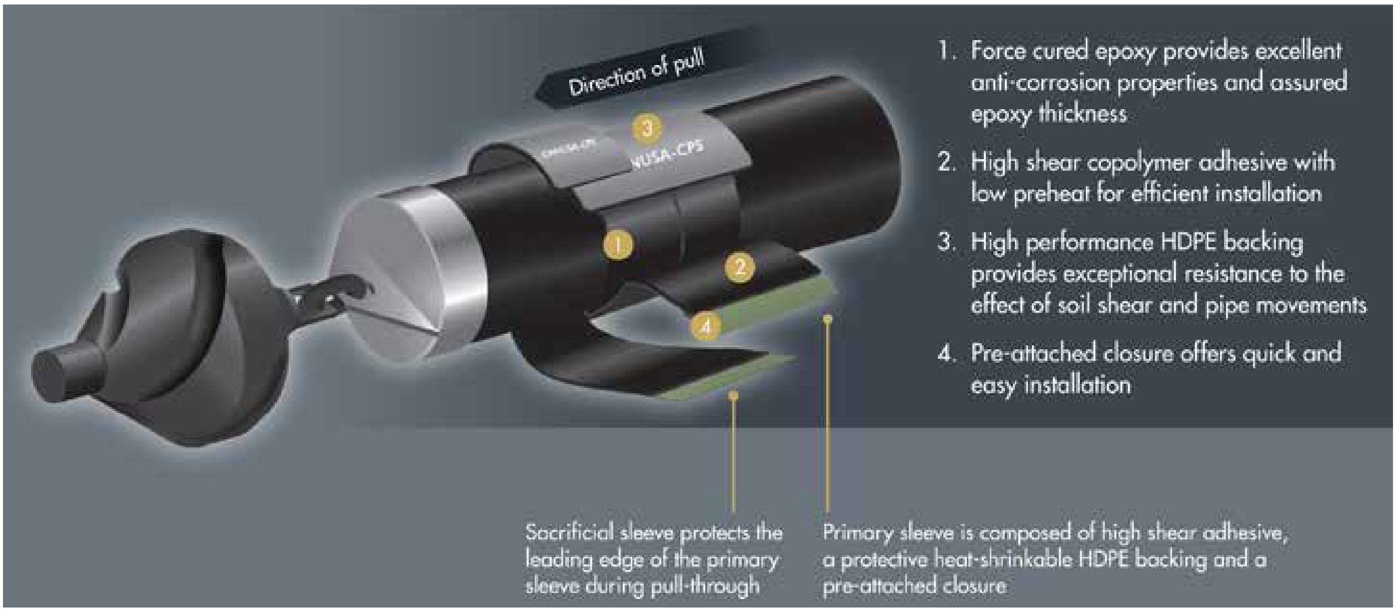

Figure 3. *The Canusa-CPS DDX field-applied coating is designed to provide enhanced HDD performance.*

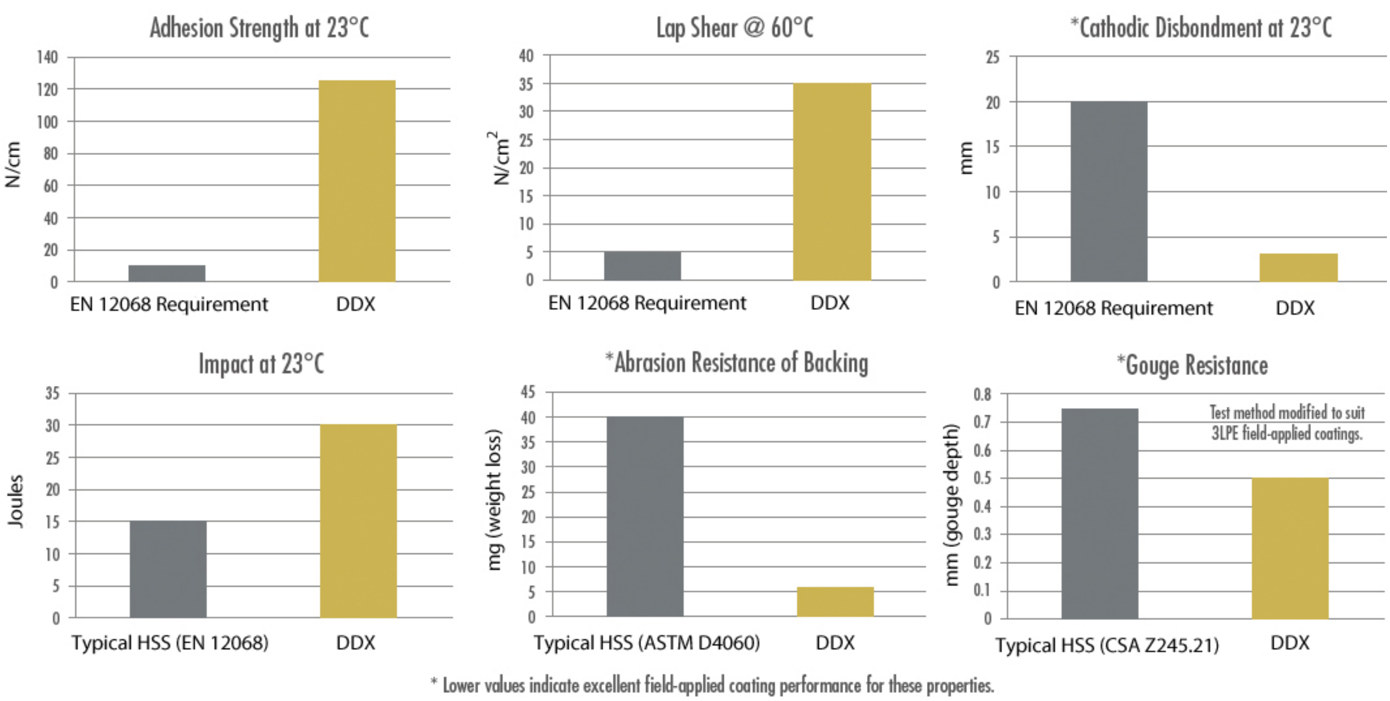

Figure 4. *Comparing Canusa-CPS DDX to typical field-applied coating norms.*

Figure 5. *Soil stress testing in soil box.*

ambient temperature and at an elevated temperature that is the same as the continuous operating temperature of the pipeline.

Impact testing

This is carried out to test the coating's ability to resist damage that can be caused when objects, such as rocks or other objects, come into contact with the coating during the HDD process or during pipeline operation. The testing is completed by dropping a spherical impactor on the test specimen with specified impact energy. The presence of damage is assessed by testing the impacted test specimen with a high voltage holiday detector. Impact testing is a very common test practice and as such it is governed by well recognised standards such as EN 12068, ISO 21809-3, and others.

Penetration testing

Also commonly known as indentation testing, this measures the coating's degree of resistance to puncture by rocks and other debris that may be intimately in contact with, and pressed into, the protective coating over a period of time. The penetration testing as per EN 12068 and ISO 21809-3 is carried out by placing an indentor on the coating under a specific pressure for a certain period of time at a specified temperature. Residual thickness or the penetration depth at the area of compression is recorded.

Soil stress testing (or soil box testing)

This test simulates the soil stress on the protective coating caused by marginal and continuous back and forth movements of the buried pipeline for the duration of its service time. Although the test standard EN 489 was developed for preinsulated pipelines in district heating, a similar testing procedure as outlined in Section 5.1 of the test standard can be used in the testing of protective coatings on HDD pipelines to assess the immediate impact caused by the pull as well as the long term impact caused by soil stress and pipe movements. Accredited third party laboratories with the appropriate sand box apparatus can be contracted for performing the soil stress test on the protective coating. Typically, the protective coating is applied on a pipe as per the manufacturer's application procedure, the pipe is placed in the soil box and loaded with sand, and a specified pressure is applied on the sand. The pipe will move forward and backward at specified speeds over a specified number of cycles. Once the test is complete, the protective coating is examined for visual damage.

Peel adhesion testing

This determines the degree of adherence of the protective coating to the pipeline substrate. Peel testing is a very common testing practice, and it is governed by many international testing standards, including EN 12068 and ISO 21809-3. The testing is conducted by peeling off a strip of protective coating in the perpendicular direction to the pipe substrate at a constant rate of speed using a tensile testing machine. The force per area width required to peel off the coating determines the adhesion or peel strength of the coating. Peel adhesion testing is usually conducted at ambient temperature and at an elevated temperature that is the same as the operating temperature of the pipeline.

Cathodic disbondment resistance testing

This measures the coating's ability to resist disbondment caused by electrical currents from the cathodic protection systems. The test is carried out on applied protective coating samples at ambient and at maximum continuous operating temperatures or up to maximum temperature of 95˚C. An artificial holiday is created by drilling a hole at the centre of the coating, extending down to the steel substrate. An electrolytic cell is created by mounting a small plastic pipe perpendicularly at the centre of the holiday. The cell is filled with NaCl electrolyte, and a specified electric potential is applied between the working electrodes over a specified period of time (usually 28 days). At the end of the testing, the test specimen is rinsed, cleaned with water and dried. Radial incisions are made outwards from the drilled holiday using a utility knife, and the coating is gently pried off from the holiday edge until firm adhesion is encountered. Average disbondment from the ends of the holiday to the area of firm adhesion determines the cathodic disbondment results. A detailed testing procedure can be found in most field joint coating standards, including EN 12068 and ISO 21809-3.

Further testing

Testing of pipeline coatings should not be limited to the aforementioned properties. Properties such as hot water immersion resistance (ISO 21809-3), thermal aging resistance (EN 12068 and ISO 21809-3), low temperature flexibility (ASTM D2671-C), specific electrical insulation resistance of the outer layer (EN 12068 and ISO 21809-3), hardness of outer the layer (ASTM D2240), tensile strength and elongation of the outer layer (ASTM D638), and volume resistivity of the outer layer (ASTM D257) are some key properties that also need to be assessed in order to select the appropriate protective coating for anti-corrosion and anti-abrasion. Since there are not any well recognised standards governing the requirements of protective coatings in directionally drilled pipelines, one must be diligent in selecting available standards and test methods and comparing against available protective coatings.

A field joint coating system for HDD applications

With a growing requirement in the industry for robust field joint coatings for HDD applications, Canusa-CPS has successfully launched many HDD-specific technologies over the years. This includes the DDX system, a directional drill pipeline field joint coating system that provides excellent anti-corrosion and class-leading anti-abrasion properties for 3LPE and FBE factory-applied pipelines operating up to 70˚C, while also incorporating a simple and consistent application procedure.

The DDX system (Figure 2) incorporates a 3-layer design to provide enhanced corrosion and abrasion resistance performance through its force cured liquid epoxy applied directly to exposed steel followed by the application of primary and sacrificial DDX field joint coating systems. The primary DDX system overlaps and chemically bonds to the ends of the factory-applied coating and to the epoxy coated steel surface in the middle. A narrower sacrificial component is applied at the leading end to the direction of pull, which provides added protection at this critical area during the HDD process.

As mentioned, the factory and field-applied coating systems used on directionally drilled pipelines must be designed to resist the extreme forces associated with the HDD operation, while still providing the required resistance corrosion over the operating life of the pipeline.