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Pipe Preservation During Trenchless Installations: There's No Need to Take Unnecessary Risks

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ABSTRACT

Corrosion is the first cause of pipeline incidents, and one of the most important responsibilities of a pipeline engineer is to choose the right strategy to protect the pipes from it. In trenchless installations, this aspect is even more important as interventions are not possible during the design life of the pipeline and usually such crossings are located in environmentally sensitive areas.

Currently, pipeline operators and designers choose between very robust versions of three-layer polyolefin (PE/PP) coatings, hoping the additional thickness will compensate material losses due to abrasion during installation, and relatively thin coatings with very high adhesion properties. In such situation, they expect the coating to perform better in combination with a cathodic protection system in the areas where the steel was exposed due to damages to the coating.

In both cases, practical experience has shown that damages cannot be avoided. Currently, specifically on pipes that are installed by trenchless processes, the available methods for identifying where the coating was damaged cannot provide absolute or accurate information on the location, size and geometry of the damages. Moreover, even though cathodic protection verification at HDD locations can be validated close to the starting and final points of the crossings; the region between can only be assumed and thus is a questionable strategy.

This paper gives evidence on why these strategies are not valid and provides a technical comparison of properties between pipeline coatings used in trenchless installations. It also introduces an engineered mechanical protection system that has been successfully used by German companies for the past 20 years with an impeccable track record. Such a solution is of particular importance to allow the trenchless industry to achieve longer and safer crossings.

Key words: Trenchless crossings, pipelines, horizontal directional drilling, coatings, mechanical protection, abrasion resistance overlay, ARO, glass reinforced plastics, composite materials, cathodic protection.

INTRODUCTION

According to a research aimed to check coating quality of pipelines installed by Horizontal Directional Drilling, during the period between 2005 and 2016 in Northern Continental Europe, over 10% of long (above 500 m) trenchless crossings required further investigation of anticorrosion coating condition after its installation creating delays and cost overruns. In all these cases, the factory applied anticorrosion coating and/or the field joint coating system was not specifically designed to withstand the stresses of a trenchless installation. The situation is similar on other parts of the world due to lack of engineering standards addressing the problem on how to protect steel pipelines during trenchless installations.

Most common problems of these coatings are related to their poor resistance to abrasion (i.e. polyethylene) or scratches with sharp objects (i.e. polypropylene) or low shear strength (i.e. cement based solutions). Another common cause of failure is the defective design of the transition area between the factory and the field applied coatings, where a protuberant shape is created and where loads are drastically concentrated.

In North America, the preference is to use relatively thin anticorrosion coatings (i.e. fusion bonded epoxy) with very high adhesion to the steel, sometimes in combination with an abrasion resistant overlay coating. The philosophy is to allow for damages to the anticorrosion coating, with the expectation that the cathodic protection system can stop corrosion at these bare steel areas. Currently, specifically on pipes that are installed by trenchless processes, the available methods for identifying where the coating has been damaged cannot provide absolute or accurate information on the location, size and geometry of the damages. Moreover, even though cathodic protection verification at pipeline sections installed by Horizontal Directional Drilling (HDD) can be validated close to the starting and final points of the crossings; the region between can only be assumed and this a questionable strategy.

The basic mechanisms of coating failures during trenchless installations are shown, a technical comparison between different systems is provided and the benefits of adding an engineered mechanical protection system that has been used for almost 20 years with impeccable track record effect are discussed.

THREE LAYER POLYETHYLENE/POLYPROPYLENE COATINGS

Three-layer polyolefin (polyethylene -PE- or polypropylene - PP) coatings have been used for over 35 years with great results and they now account for almost 50% of new steel pipeline projects globally. Due to their acceptance and preference by pipeline operators, many steel pipes suppliers incorporated three-layer coating lines to their mills to satisfy a strong demand for this product.

At the same time, the trenchless industry has made sustained progress at achieving longer and larger crossings and therefore, most of these pipeline operators tried to install pipelines protected by three-layer coatings with varied results. In some cases, a reinforced layer of its outer layer was specified with the expectation of compensating losses due to abrasion. Many operators studied the use of polyolefin coatings exposed to high cutting and abrasive loads typical of trenchless installations and concluded that to obtain a suitable protection it is required to double or triple the coating thickness. However, other problems are created by such a simplistic approach. An image of a damaged polyethylene coated pipes is shown in Figure 1.



Figure 1: Deep scratch damage during an HDD project

The application process of three-layer coatings is primarily achieved by sleeve or side extrusion of the polyolefin topcoat, where the material is brought to a fluid state achieved by friction between plastic particles and external heating. Immediately after the fluid thermoplastic film is laid onto the pipe surface, water jets cool the material back to its solid state. The consequence of the sudden change of state is the creation of internal stresses that are released as soon as the pipes are subjected to additional stress during installation. These residual stresses increase with an increased coating thickness. Adeniran et al.^[1] explained the mechanisms involved. Figure 2 shows a crack through the coating reaching the base steel, which occurred during a HDD crossing.

These internal stresses are the root cause of cracks in the PE/PP anticorrosion coating that appear when pipe is bent to accommodate the shape of the crossing. They are also responsible for disbonding the coating at the pipe ends when pipes are exposed for a few months to the environment and the bare steel at the end of the pipes (cutbacks) starts to corrode.



Figure 2: Propagated crack due to release of internal stresses on a 3LPP coated pipe

Another aspect that is disregarded by specifying a thick topcoat layer is the complexity of executing standard quality control tests to the anticorrosion coating system as they are designed to be performed in coatings not exceeding 5 mm thick. Hanging mass/constant peeling speed adhesion testing are mandatory on all international standard for three layer pipe coating, but difficult to perform at increased thickness. For this reason, pipe coating experts do not recommend applying these systems in a single step when thickness is above 5 mm.

A. Dam extensively tested polyolefin topcoats for resistance to sharp objects as part of Gasunie efforts to determine the most suitable coatings for trenchless installations^[2]. The most interesting conclusion was that polypropylene showed ca. 25% higher resistance to scratches when compared to polyethylene, but the former is drastically damaged by very sharp shapes, which is consistent with field experience in France as seen in Figure 3. In this case the crossing was done through a geological formation of 80% chalk and 20% basalt rock that destroyed the polypropylene.

Another weakness of thick polyolefin coatings is the substandard available field joint coating methods used along with these systems that are here below explained:

- Solid polyurethane infill: it encompasses filling of the gap created at the field joint area with a polyol isocyanate mix that reacts and hardens. It is a very simple process and extensively used, but the adhesion between this material and the factory applied coating is low (under 3 MPa Pull-off adhesion according ASTM D4541^[3]) and thus disbondment at the transition areas are frequent. An improved version of this system includes thermal welding of a polypropylene outer sheet that is applied at a step created by machining the factory applied coating. The improvement encompasses additional complexities and makes the solution more difficult to be widely implemented.
- Injected Molded Polypropylene: this system consists of positioning a high-pressure mold around the field joint area and injecting molten plastic material in the gap between the mold and the pipe. While it is a much stronger solution than polyurethane infill, molds costs are very high and thus there is limited offer for such solution.
- Flamed Spray Polypropylene: in addition to above methods, the gap at the girth weld area can be filled by spraying polypropylene powder that is projected to the pipe surface through a flame. The achieved protection is of good quality only if applied by very experienced operators as risks of burning the material or not getting a consistent bonding to the anticorrosion layer are high. Moreover, it is a very slow process and requires induction heating for application of the anticorrosion layer before the projection of the polypropylene and thus its penetration in trenchless projects was low.



Figure 3: Deep scratches occurred due to gouging of polypropylene coating