New Developments in Polypropylene Field Applied Joint Coatings

CEOCOR Conference – May 2003

Authors: N. Gritis, D. Tailor, L.Civardi
Canusa-CPS

SYNOPSIS

In the last decade, we have seen an increasing use of high performance mill-applied pipeline coatings, such as the 3-layer polyethylene (PE); and more recently the polypropylene (PP) coatings for the more demanding applications. The mill coatings are applied under controlled plant conditions. The field joint systems, however, have to be applied under less controlled conditions, and yet provide performance and quality consistent with plant applied coatings. Polyethylene heat-shrink sleeves are the most commonly used protection for the field joints of PE coated pipelines due to their compatibility, ease of application, reliability and extensive track record. However, there has been an absence of a more universally accepted field joint solution for PP coated pipelines. This paper describes the breakthrough technology in polypropylene field joint coatings. The products described have been tested and successfully used on various projects by leading engineers and contractors.

1. INTRODUCTION

Steel pipelines for underground and ~~off-shore~~offshore applications are exposed to increasingly harsh and corrosive conditions. An example is the Bluestream project in the Black Sea. The sub-sea environment of this project required coatings with higher corrosion, temperature, and mechanical resistance. Three-layer polyethylene (PE) coatings have been traditionally used for such applications. However, in the past few years, with more demanding and harsh conditions being encountered, ~~three-layer~~3-layer polypropylenes (PP) are increasingly being used. These are applied in a factory setting with controlled and automated plant conditions. The welded field joint is often coated in ~~a~~ less controlled and often inclement conditions. Unless properly specified, the field joint will become the weak link of the pipeline. In order to ensure that the quality of the field- joint coating is as good as the mill-coating, it is necessary to have a good joint coating product as well as a reliable, repeatable installation method that can be used in variable field conditions.

2. CURRENTLY AVAILABLE FIELD JOINT SYSTEMS

Traditional field joint coatings that have been used with polypropylene lines have included the following:

1. Flame-sprayed PP. With this method, a special gun is used to spray the PP and the adhesive powders with the aid of a flame onto a FBE primer. While this is a convenient technique for odd-shapes such as valves and fittings, it is susceptible to poor adhesion if the powdered materials are not fully activated. Safety concerns exist and because of the specialized equipment required, the method is also costly and impractical for small projects.

2. Two-layer FBE/sintered PP Coating. This method involves flock-applying PP powder over a FBE primer on a heated joint. Successful sintering relies on the pipe heat, and therefore is limited to about 1.5 mm thickness, and is susceptible to poor adhesion over the mill coating due to lack of sufficient heat on the surface.

3. Coextruded PP Sheet applied over sintered adhesive/FBE powder layers is the more commonly used system these days. After induction heating, the FBE and PP adhesive powders are sintered onto the surface by flock spraying. Then a PP sheet is wrapped around the joint under heat and is pressed down with a press-roller. Typically, a few layers of thin sheet are applied to build up the thickness. Successful sintering requires temperatures of 240ºC, which can easily damage or delaminate the mill-coating. Also, there can be an issue of not getting the mill-coating surface temperature high enough to secure a proper adhesion of the PP sheet, particularly if the mill-coating is more than 2.0 mm thick. The use of raw material powders and unfinished sheet in the field also introduces variables that are best controlled in the factory.

4. Injection Molding Polypropylene. This system is uses a mold for installation over the joint. This is a high capital and complex method, where literally the injection-molding factory is taken into the field to apply the joint coating. The economics restrict it to big jobs, as well as to field conditions ~~which~~ that are well controlled.

5. Polyethylene based Heat-Shrink Sleeves with adhesives that are compatible with the polypropylene coatings. These are suitable for less demanding applications, but the polyethylene does not have the performance of polypropylene coatings.

   Most of these systems require specialized equipment and labour, which increases the cost of the project. Recently, BP announced the need for major cost savings in our industry. Any field joint solution needs to consider this mandate. What has been missing in terms of a polypropylene field-joint solution are heat-shrink sleeves, which today are the most successful and widely accepted joint-finishing method for 3-layer PE coatings. Heat-shrink sleeves have had a successful track record for over 30 years.

3. KEY REQUIREMENTS FOR FIELD JOINT COATINGS

Pipeline coatings provide the corrosion protection to the pipe and thereby maintain~~s~~ the original integrity of the steel. The field-joint coating is applied as a discrete operation in the field where the conditions tend to vary. However, a good ~~polypropyelne~~polypropylene field-joint coating must achieve the following requirements:

1. Primary corrosion protection of the steel, which is provided by the epoxy primer.
2. Mechanical protection of the joint as measured by impact strength and indentation. This is provided by the polypropylene backing.
3. Form a barrier to ~~the~~ environmental elements ~~in the environments~~ such as water, chemicals, and gases. The adhesive binds the backing to the joint to provide a seal ~~to~~against the elements.
4. Bond between the mill-coating and field-applied coating, not only to provide a seal to the joint, but also to form a 'continuous' coating to obtain pipeline integrity.
5. Provide the performance at the operating temperature of the pipeline, 110 ºC or even as high as 130 ºC for some polypropylene coated lines.
6. Achieve all of the above in a cost-effective manner without the need for specialized sub-contractors.

Over the last few years, Canusa has supplied a patented heat-shrink system for PP coated pipes. This system has been used successfully in Algeria, Syria, Saudi Arabia, UAE and Oman. This entailed a polyethylene based sleeve with separate strips of adhesives to bond to the PP coating, and subsequently applying an epoxy layer on the sleeve edges to provide soil stress resistance. This system is suitable for lower demanding applications. However, there continued to be a demand from industry for a heat-shrinkable polypropylene joint coating made from polypropylene materials similar to those used on the parent mill-coating.

4. EVOLUTION OF POLYPROPYLENE HEAT SHRINKABLE TECHNOLOGY

A PP heat-shrink sleeve system has eluded scientists and engineers until now due to the difficulty in crosslinking polypropylene. PE heat-shrink sleeves are made by in-plant radiation crosslinking of the PE sheet and subsequent~~ly~~ stretching of the sleeve to render it shrinkable. However, PP sheet undergoes degradation due to chain-scission when subjected to radiation. Similarly, chemical crosslinking also requires free-radical reactions, which invariably degrade the PP.

Recently the scientists at Canusa, a division of ShawCor in Canada, were able to impart crosslink in the polypropylene structure, while controlling the chain-scission reaction using a unique, in-house, proprietary crosslinking technology. This is a significant breakthrough in the plastics industry. Canusa has taken this technology and applied it to the design and manufacturing of PP heat-shrink sleeves. This also required development of special polypropylene adhesives suitable for heat-shrink sleeve applications, as well as novel manufacturing techniques.

In developing the PP heat-shrink sleeve system, the primary objective was to obtain a field-joint coating that matched or exceeded the characteristics and the performance of the mill-applied pipeline PP coating. In order to set a ~~bench-mark~~benchmark for the new system, the following key pipeline industry standards were used:

1. NFA-49-711 French Standard for Steel Tubes – Three-layer External Coating Based on Polypropylene Application by Extrusion, Nov. 1992.
2. Shell Standard DEP31.40.3031-Gen.
3. Total Standard SP-COR-356.
4. DIN Standard 30678.

5. DESCRIPTION OF THE POLYPROPYLENE SLEEVE SYSTEM

The PP heat-shrink system ~~comprises~~consists of two components:

1. A liquid epoxy primer.
2. Heat-shrink sleeve consisting of a PP backing coated with a PP adhesive.

Unlike the FBE powder, the liquid epoxy primer does not require excessive steel temperatures ~~like~~ of 240ºC, which is time consuming, energy intensive, and could damage the mill-coating. The primer cures below 150ºC, and provides excellent properties, including elevated temperature cathodic disbondment comparable to the FBE.

Unlike the current systems, which require the raw material mixing and fabrication in an unpredictable field environment, or taking the complex factory equipment to the field, the heat-shrink sleeves have been prefabricated into usable sheet or tube product in ~~the~~ controlled factory conditions. This ensures a consistent quality and performance on every field joint.

The characteristics that clearly define the superior performance of the system is the minimum high peel strength values of 70 N/cm at 100ºC and indentation values of less that 0.4mm at 110ºC.

6. INSTALLATION DEVELOPMENT

The key to achieving a good quality coating on the field joint is having not only a good system, but also a controlled installation method that provides reliable and repeatable good results. In the development of the PP heat-shrink sleeve installation technique, four key ~~pre-requisite~~ prerequisite parameters were considered.

1. Joint steel temperature had to be minimum 180ºC, to achieve a bond of the sleeve adhesive.
2. The mill-coating surface temperature had to be a least 140ºC as a pre-heat, and then exceed 160ºC during the sleeve installation.

3. Primer on the steel required 140ºC for curing.
4. A certain pressure was required on the adhesive during the installation to~~affect~~ effect ~~the~~ adhesion.

The required temperature was readily is uniformly achieved using an induction coil.

Pipe Diameter:	600 mm
Wall Thickness:	30 mm
PP Coating Thickness:	5.0 mm
Total Joint Length (Cutback):	300 mm
PP Sleeve:	450 mm width, 2.6 mm thickness

The ~~required~~ pressure required to obtain successful adhesion is obtained by the hoop-stress applied by the shrink force of the sleeve, as well as the pressure generated due to the crystalline contraction of the sleeve backing.

There were significant hurdles encountered at the initial stages of development. In order to get the PP coating surface to the required 140ºC, the steel temperature had to exceed ~~over~~ 240ºC. At this temperature, the coating can delaminate from the pipe and can be severely damaged. The epoxy primer can also degrade. Therefore, the key is to find a PP surface temperature of 140ºC, while maintaining coating integrity.

This was achieved by use of conductive bands that are tightly wrapped on the PP mill coating adjacent to the cutback. The induction heating of the pipe joint also heats up the ~~steel~~ conductive bands. In this configuration, the coating is heated from inside by the pipe steel, and on the outside by the conductive band. An additional benefit of the conductive bands was that they act as molds around the mill-coating, preventing delamination, bubbling, or any damage due to the high heat. A patent is pending for this heating technology.

In experiments carried out on ~~other~~ pipes with less that 2.5 mm thickness, it was found that when the steel temperature was at 200ºC, the heat could conduct through the 2.5 mm coating, and the surface temperature reached the desired target without the aid of the conductive bands. However, with this method, the use of flexible silicone bands wrapped on the coating prevented the lifting or delamination of the coating during the preheating of the steel. A patent is also pending for this technology.

7. SLEEVE INSTALLATION PROCEDURE

The installation procedure that has been developed and successfully used on many projects is described below:

1. The field joint is gritblasted to a standard of SIS Sa 2 ½ or equivalent.
2. After cleaning the coating surface, the conductive bands are wrapped onto the coating.
3. Assuming the joint is dry from the heat applied ~~prior to~~before the gritblasting, the epoxy primer is applied using application pads.

4. The joint is heated with the induction coil to achieve the proper preheat.
5. The coil and the conductive bands are removed, and the heat-shrink sleeve is placed and ~~centered~~centred over the joint so that a 75mm overlap over the coating is obtained.
6. The sleeve is shrunk with a conventional propane torch.

The installation is simple and repeatable to get consistent results. The critical step is in achieving the required preheat on the steel and the coating, and this is easily attained by~~the~~ timing the induction coil, which is previously calibrated. The second critical item is the heat applied for shrinking the sleeve.

8. SUMMARY

The technological breakthrough of being able to crosslink polypropylene without any adverse effects has allowed the development of the polypropylene heat-shrink sleeve system. The system developed by Canusa uses the same polypropylene backing and adhesive materials commonly used in the factory applied coatings. The sleeve backing and the adhesive are prefabricated in the factory to ensure quality application in the field, where the variables cannot be readily controlled. The use of the induction coil and unique conductive heating bands also ensures consistent installation parameters and quality. The result is a field-joint coating that is state-of-the-art, economical, and provides performance similar to the parent mill-coating. This joint solution also offers major cost savings~~as well~~, since it does not require specialized equipment and complex installation procedures. Trained contractors can easily apply the system to the quality standard required by the owner. Because of the many benefits over traditional systems, the polypropylene based heat shrinkable sleeve has already been used on many projects around the world.

REFERENCES

1. BERTI E. and CULZONI F., Field Joint Coating for Steel Pipe Three Layer Polyolefin Coated, 13^{th} International Conference on Pipeline Protection, September 29, 1999.

2. MOOSAVI, A.N., Advances in Field Joint Coatings for Underground Pipelines, Materials Performance, August 2000.

3. HAIMBL, J.G., GEISER, J., Polyethylene Coatings in Europe: a look back on 30 years of experience, Prevention of Pipeline Corrosion Conference, October 31, 1995.

4. NOZAHIC, D., LEIDEN, L., BRESSER, R., Latest Developments in Three Component Polyethylene Coating Systems for Gas Transmission Pipelines, NACE 2000.

Figure 1. Polypropylene Heat Shrinkable Sleeves

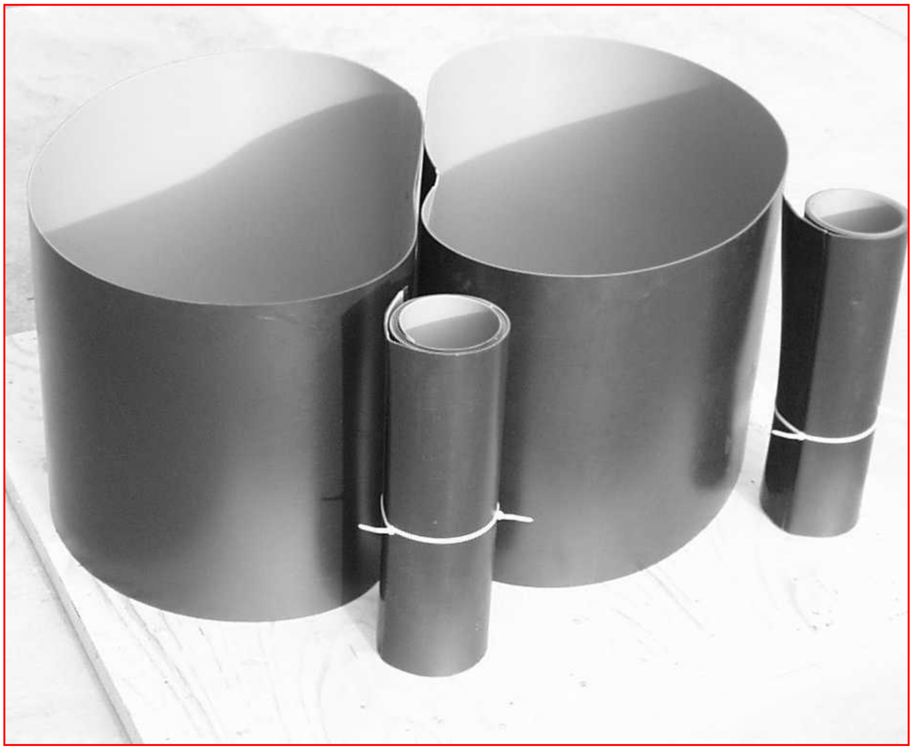
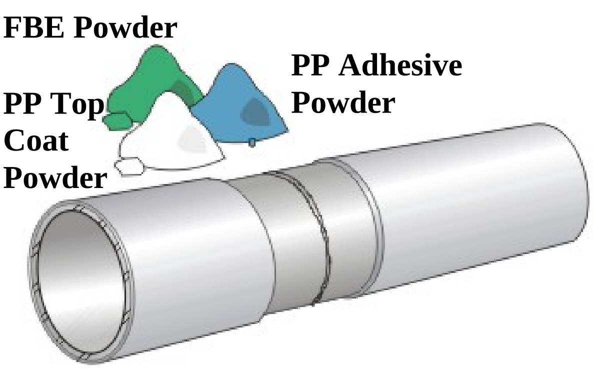


Figure 2. Field Joint Systems: Old & New Polypropylene Heat Shrink System

Traditional systems involve the mixing of raw materials in variable field conditions. Polypropylene sleeves are manufactured in a controlled facory setting and then shipped to the jobsite to maintain quality.

Traditional PP Systems



Polypropylene Heat-Shrinkable Sleeve

Figure 3. Liquid Epoxy Primer Application

Figure 4. Induction Heating

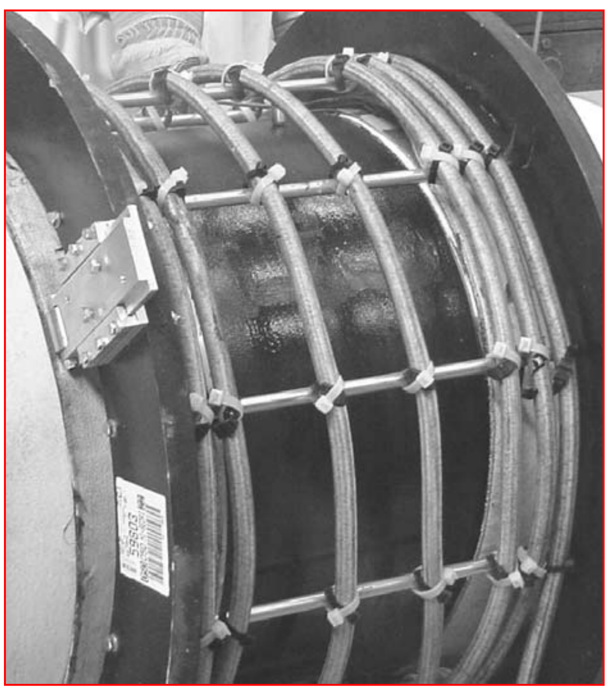


Figure 5. Sleeve Positioning

Figure 6. Sleeve Shrinking