The evolution of coatings

Jim Banach, SPC, Canada, illustrates the evolution of girth weld coatings over time, from tapes and coal tar wraps to urethane and liquid epoxy.

In the early 1980s, 100% solids urethane was first used in North America to coat pipeline girth welds. Urethane supplanted fusion bonded epoxy (FBE) used for coating girth welds where the mainline was coated with FBE. Liquid urethane had the advantage of lower cost and improved performance. At that time, newly constructed pipelines were mainly coated with FBE. The use of tapes and coal tar wraps declined sharply for mainline and girth weld coating.

With operating temperatures increasing, girth weld coating needed to meet this challenge. Urethanes could be used where operating temperatures were less than 50˚C. With FBE then rated up to 80˚C, 100% solids urethane coatings were replaced with 100% solids epoxy coatings. Here, liquid epoxy offered a lower cost solution and improved performance.

New challenges for girth weld coating

In Europe, South America, Africa, and to a lesser extent in North America, three-layer polyethylene (3LPE) and three-layer polypropylene (3LPP) have gained wide acceptance. These coatings are robust, have reduced handling damage compared to FBE, and in the case of 3LPP can be rated up to 150˚C.

Tapes and heat shrink sleeves have not performed well as a girth weld coating with these aforementioned mainline coating systems. FBE is not used because of high application temperature requirements that would cause thermal degradation of the 3LPP or 3LPE.

Bonding of liquid epoxy to PE and PP posed a problem. However, with advances in technology, the issue of bonding of liquid epoxy to PE or PP has been solved.

Surface treatments

A property of polyethylene and polypropylene is low surface energy. These materials typically have a surface energy ranging from 25 - 40 dynes/cm^2. This low surface energy is the result of having very few polar functional groups on the surface. Polar functional groups are required for adequate bonding of liquid coating to a polyolefin surface. As a consequence of this, an untreated polyolefin surface is a challenging substrate on which to adhere liquid epoxy coating.

Oxidative surface treatments have been found to increase the surface energy of polyolefin substrates, and thereby significantly improve both adhesion and performance. Oxidative treatments include both flame and blown-ion plasma treating.

Flame treatment

PP and PE have a chemically inert and non-polar surface, resulting in a low surface energy. Therefore, a surface treatment is required to enable bonding of liquid epoxy and urethane coating to these surfaces. One practical method is to increase the surface energy of PP and PE using flame treatment.

Flame treatment of polyethylene has been used for over 60 years. One early application was the treatment of the exterior of PE containers to enable ink used for product identification to adhere to the PE.

Extensive testing and trials were carried out by SPC at its lab in Langley, British Columbia, to develop an effective procedure for flame treating polyolefin that could be adapted for field use. The degree to which the surface energy of PP and PE is enhanced by oxidative treatment depends on the speed at which the treating flame passes over the substrate, and the distance of the treating head from the substrate.

SPC personnel constructed an apparatus (Figure 1) that allows for the control of both of these parameters. The surface treatment apparatus (STA) consists of a variable speed air driven motor attached to a winch. This winch is in turn attached to a moveable trolley by a metal chain. Activation of the air motor allows the trolley to be moved at speeds from 10 - 100 fpm.

Effective treatment requires that the most oxidising part of the flame contact the coated surface. A properly adjusted flame has two visually distinct areas: a light blue, relatively opaque inner flame, and a darker, more transparent, outer flame. The fuel for the burner head is a mixture of air and propane. The most oxidising part of the flame is located in the outer flame, usually approximately 2 - 3 cm from the tip of the inner flame. This can be determined by passing various parts of the flame over a section of the polyolefin coating and checking magnitude of surface energy increase. The surface energy can be measured using a series of calibrated dyne pens or water. Ideally the surface energy should measure

Figure 1. Surface treatment apparatus.

Figure 2. Flynn Burner flame pattern.

72 dynes/cm^2 which can be measured using water. If water wets the surface and does not bead, then the surface energy is a minimum of 72 dynes/cm^2. Figure 2 shows typical flame pattern at the tip of a flame treating head. The flame treating head, manufactured by Flynn Burner Corporation, consists of a special multi-port burner fed by propane and compressed air.

Figure 3 shows the STA with the treating head mounted above the trolley track. The head can be adjusted to achieve the optimum height above the moving substrate. For field application, the head would move past the surface to be treated.

Once the flame has been set and the correct area of the flame located, the polyolefin can be treated. During this procedure, care must be taken to ensure the coated surface is not thermally damaged by the flame. A speed of 50 ft/min. was deemed to be ideal as no surface damage was observed. At this speed, the surface energy increased by approximately 7 dynes/cm^2 per pass. Five passes are generally required to raise the surface energy to between 66 - 72 dynes/cm^2.

A flame treatment unit developed for field use is shown in Figure 4. A hose connects the fuel supply to the burner head. The operator holds the burner head such that the surface to be treated is in the oxidising part of the flame. Several passes are required to achieve the desired surface energy.

Plasma surface treatment

As with flame treatment, SPC tested a plasma system (manufactured by Plasma Treat) for oxidising the surface of a polyolefin coating. The same STA was used to determine an effective procedure that could be adapted for field use. Figure 5 shows the lab set-up for trials with the plasma system. The unit shown delivers plasma with a jet rotating at 2.000 rpm. The Plasma Treat unit raised the surface energy of the polyolefin to between 66 - 72 dynes/cm2 in one pass at 10 fpm.

Functional coating testing

Liquid epoxies and urethanes have been used as a girth weld coating, combined with a FBE mainline system, for over 35 years. Only recently have liquid coatings been accepted for use with 3LPE and 3LPP. Initially, liquid coatings were applied to blast roughened PE or PP. With the advances in oxidative surface technology including a system for field use, flame oxidation of PE and PP has gained acceptance.

As previously mentioned, tapes and shrink sleeves did not offer the performance requirements needed for a girth weld coating for use with PE and PP. In additional to meeting Standards testing on a steel substrate, SPC conducted adhesion testing on two of its girth weld coatings applied over flame treated PE and PP. An epoxy and a urethane were tested.

Liquid epoxy and urethane applied over a blast-roughened PE and PP have pull-off adhesion values that

Figure 3. Surface treatment apparatus using Flynn Burner head.

Figure 4. Treatment of PE coating using Flynn Burner head.

Figure 5. Surface treatment apparatus using plasma system.

range from 800 - 1000 psi. These same coatings applied over flame treated PE and PP have adhesion values ranging from 2300 - 2400 psi.

Flame vs plasma treatment

Although much of this article has been focused on flame treatment, plasma treatment may be a viable option. The adhesion values for liquids on PE and PP show similar results for both flame and plasma surface treatment. However, with plasma, thermal damage to the substrate coating is not an issue and increasing the substrate coating surface energy is faster than with flame treatment.

A field unit for plasma treatment needs further development.

Conclusions

Liquid epoxy and urethane is a viable and effective girth weld coating to be used with PE and PP mainline coating systems.

Both flame and plasma treatment increases the surface energy of PE and PP to enable the use of liquid epoxy and urethane as a girth weld coating.

Flame treatment systems are, at present, in use in the field to provide oxidative treatment for PE and PP substrates.