Jim Banach (USA) and Jeevan Menon (Australia) discuss the development and use of Liquid Polymer Epoxies (LPE) for Girth Welds where the mainline coating is three layer Polyethylene (3LPE)

Adhesion of liquid Polymer Epoxy (LPE) coatings to 3 LPE/3LPP Coated Pipelines

Polyethylene (PE), High Density Polyethylene (HDPE) and Polypropylene (PP) Pipeline coatings are all difficult substrates to coat to or paint over due to their low surface energy. They are chemically inert and have a non polar surface , thereby making it difficult for the coatings to “wet out” or adhere to . The Field Joint coating must adhere to the prepared steel surface as well as the overlap onto the Parent PE or PP coating .
To ensure the adhesion to the PE/PP substrate , surface treatment is required to increase the surface energy and enhance the bond of the liquid LPE coating to the PE/PP mainline coating.
This article exams the various Surface treatment techniques to ensure adhesion to the PE/PP mainline coating

Background

Pipeline coatings have undergone dramatic technological changes over the past two decades. Coatings must now perform at higher in-service operating temperatures, must not be damaged in handling during construction or in operation by soil stress or soil movement, and must provide exceptional corrosion protection. Coatings also must be user friendly and must be able to be applied in a mill or in the field.
Those who practice the science of corrosion control know that coatings are the primary means of corrosion protection for a buried pipeline. This applies to new construction or to pipeline rehabilitation. Although cathodic protection is applied to buried or submerged pipelines, it is considered the second line of defense against corrosion. Therefore today’s coatings must provide better protection than their predecessors, continue to function under severe operating conditions, and be applied under less than ideal conditions. These requirements also apply to the field-applied girth weld coating systems.

Coating selection

Over the last 30 years in North America, the mainline coating of choice for most medium to large diameter pipelines has been fusion bonded epoxy (FBE). For the past 20 years on these pipeline projects, urethanes and more so today, LPE Liquids , have become the coating of choice for girth welds, valves and fittings. Some of these same North American companies are now considering three layer polyethylene (3LPE) systems as a mainline coating system.
3LPE coatings for pipelines are widely used in Europe, Australia and in the Asian region . Typically, tapes or shrink sleeves have been used to coat the field girth weld. Of late, LPE Liquids have been tested and approved for use as a girth weld coating system for the 3LPE/3LPP coated Pipelines . Although LPE liquids have superior corrosion protection performance when compared to tapes and shrink sleeves and meet the aforementioned performance requirements of mainline coating systems, bonding to polyethylene has been cited mistakenly as a major concern.

Surface treatment :

As a practical field method, the surface of polyethylene can be transformed from non polar to polar by chemical or flame treatment, thereby increasing the LPE liquid coating to polyethylene bond strengths.
In addition to chemical and flame treatment, mechanical abrasion can be used to enhance bonding of liquid coatings to polyethylene.

Flame Treatment

Flame treatment of polyethylene has been around for over 50 years. One of the early applications was the flame treatment of polyethylene containers, to allow links used for product identification to adhere to the PE surface.
With flame treatment, the combustion action of a hydrocarbon gas releases free radicals during formation of the flame. These free radicals penetrate the polyethylene and modify its surface wettability thereby increasing the surface energy of the polyethylene. The surface to be treated must free of contaminants and an oxisdising flame must be used to achieve optimum surface energy. Figure 1 shows a type of burner used for a flame treatment..
The surface energy of untreated polyethylene ranges from 30 -40 dynes/cm. Surface energy of the PE is easily measured using calibrated dyne solutions. A few drops each of a range of dyne solutions are dropped onto the polyethylene surface until one of the solution wets out (does not bead).

Fig 1 Burner used for Flame Treatment

Chemical Treatment

The bond of liquid epoxy to polyethylene can also be improved using primers or a combination of primers and pretreatment wash solutions. Some primers can be applied immediately prior to application of the liquid coating. Others require time to cure prior to application of the top coat.

Mechanical abrasion

Another inexpensive and effective method to enhance bonding to LPE liquid coatings to PE is to abrasive blast the PE. Tests carried out by SPC have shown that sweep blasting of the PE surface is not as effective as an aggressive roughening of the PE surface. Figure 2 shows an abrasive blast cleaned girth weld area with the FBE Toe including the PE overlap.

Fig 2 Girth weld with Blasted steel with the FBE Toe

PE coated pipe-end preparation

On a recent project, 3LPE coated pipes were supplied with the exposed FBE toe . The liquid epoxy girth weld coating was required to bond to the steel pipe surface, FBE, and PE. Here the FBE is considered to be the corrosion protection coating, whereas the PE provides mechanical protection. The bond strength of liquid epoxy to blast cleaned steel is greater than 4000 psi and over 2000 psi to blast roughened FBE.

Testing bond strength

The major concern using LPE liquids on polyethylene coatings is the lack of adhesion of the Liquids to the PE overlap and failure at the overlap resulting from expansion and contraction of the 3LPE coating.

A series of tests were conducted for each PE surface treatment. Where flame treatment was used, the surface energy of the polyethylene was raised to a minimum of 60 dynes/cm.

To simulate the effect of expansion and contraction on the epoxy to the polyethylene bond, test panels were subjected to a 10 day cyclic test prior to undergoing pull adhesion tests. Each cycle consisted of 12 hours immersion in 3C water and 12 hours immersion in 65C water. The cycle ended on the 65C cycle and the pull off adhesion test was performed within 60 minutes after the hot cycle. Pull off stubs were affixed to each test plate prior to the start of the test. Table 1 compares the bond strengths of liquid epoxy to polyethylene for various polyethylene pretreatments. An epoxy coated production girth weld is shown in figure 3.

Figure 3. Completed LPE liquid production Girth weld on 3LPE

Project example

For BP’s Quandong LNG Dapeng Pipeline exhaustive testing and certification was conducted with the use of LPE liquids on the 3LPE coated pipes . Adhesion testing on site showed excellent adhesion. In addition the LPE Liquids were also used on the HDD joints and the first trial HDD used both Shrink sleeves and LPE liquids with the resulting failure of the shrink sleeves – refer to Figures 4 and 5A&5B

Figure 4. LPE liquid on 3LPE girth weld – BP's Quandong LNG Dapeng Project China

Figure 5A – Shrink sleeves used on the 3 LPE coated pipes in the HDD BP's Quandong LNG Dapeng Project China

Figure 5B –LPE liquids used on the 3 LPE coated pipes in the HDD BP's Quandong LNG Dapeng Project China

Conclusion

There are those who believe that no coating system can be made to bond to PE, including LPE liquids and that only shrink sleeves or tapes can be used to coat girth welds. Current project experience, Testing and Approvals by SPCA confirms the superior adhesion of LPE liquids to 3LPE mainline coatings .
LPE liquids do not have the same expansion ratio as PE. However, the 3LPE system consists of a FBE primer, copolymer adhesive and a extruded PE outer layer. This copolymer prevents excessive expansion of the PE.
As shown in the Table 1 , LPE liquids bonds to PE over a wide temperature range. This has been verified by field experience and project history
LPE Liquid coatings are now being used with three layer polyethylene systems and the concerns with the epoxy to polyethylene bond has been addressed by surface treatment of the PE prior to application of the epoxy corrosion coating.

Table 1 Comparison of the bond strengths of liquid epoxy to polyethylene for various polyethylene treatment

PE Treatment	Bond Strength	Cyclic Testing
Untreated	No Bond	

Sweep blasted	500 psi	
Blast roughened	750 psi	750 psi
Flame Treatment	1100 psi	
Blast/primer		1700 psi