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Polyamide 12 in Extruded Coating Systems for Steel Pipe Protection

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Abstract

The corrosion of pipelines is one of the main problems in oil and gas industries for which a large amount of money is spent each year. Today's pipelines in the oil, gas and water transportation industries worldwide are usually protected by external coatings in conjunction with cathodic protection systems. Pipe coating solution providers are offering various types of products tailored to the needs of their clients. Some of these common pipeline coating products include two-layer and three-layer coating systems that provide excellent anti-corrosion protection to pipes. The three-layer extruded system uses one layer of epoxy powder to provide corrosion resistance, a copolymer adhesive layer and another of polyethylene, polypropylene or polyamide 12 (PA 12)as the top coat. This paper introduces the using of PA 12 in three-layer system coating according requirements established in ABNT standard 15221, and two-layer system removing adhesive layer. The important advantages of PA 12 as an encasement material are unusually high impact resistance and toughness, even at low temperatures; excellent stress cracking resistance; excellent wear resistance; low sliding friction coefficient leading to life-time extension of pipe protection and minimize environmental risks.

Keywords: pipeline, coating, three-layer, polyamide 12, encasement, polymer

Introduction

The corrosion of pipelines is one of the main problems in oil and gas industries for which a large amount of money is spent each year. Coating is the first defense line in front of a corrosive environment in which pipes have been buried. Today's pipelines in the oil, gas and water transportation industries worldwide are usually protected by external coatings in conjunction with cathodic protection systems. Pipe coating solution providers are offering various types of products tailored to the needs of their clients. Some of these common pipeline coating products include two-layer and three-layer coating systems that provide excellent anti-corrosion protection to pipes. The three layer extruded system uses one layer of epoxy powder to provide corrosion resistance, a copolymer adhesive layer to create adhesiveness between layers 1 and 3 and must be compatible with both, and another of

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polyethylene (PE), polypropylene (PP) or polyamide 12 (PA 12) as the top coat. The three-layer polyethylene and three-layer polypropylene coating systems have been successfully used on oil and gas onshore and offshore for the last 20-25 years.

Polyamide 12 is a thermoplastic polymer developed in the 1960ies. Since then, PA 12 can look back to an extensive track record in several demanding applications ranging from automotive fuel lines, through core insulation in the cable industry, and unbonded flexible pipes for offshore O&G production. Starting in 2006 the O&G industry is using tailored PA 12 grades for crucial applications like barrier and jacket layers of unbonded flexible pipes for offshore production. More than 1000 km of flexible pipes using PA 12 have been installed today.

This paper introduces the transfer of this successful technology to pipeline's protection by using PA 12 to encasement application. The important advantages of PA 12 as an encasement material are unusually high impact resistance and toughness, even at low temperatures; excellent stress cracking resistance; excellent wear resistance; low sliding friction coefficient. The paper presents the laboratory results and compares them to the requirements of the other two existing coatings for three-layer extruded system according ABNT standard 15221, and the results of the excellent adherence properties for two-layer system.

Methodology

According requirements stablished by ABNT standard 15221, some pipes were coated by extruded system and qualification tests were performed using PA 12 as topcoat.

The steel pipes surface preparation followed all requirements and the pipes surface were free from grease, oil or free oxide layer, and any other material. All pipes surface were checked and measures of roughness and salt contamination were done. The steel pipes were heated to about 180°C before coating application and the external pipe temperature was continuously monitored by an infrared optic pyrometer.

The three-layer extruded system used one layer of Fusion Bonded Epoxy (FBE) to provide corrosion resistance, a copolymer adhesive layer and another of PA 12 as the top coat. After extrusion process, some tests were performed to check the coating resistance, among them adherence, bending, impact, pull-off, peel strength, and cathodic disbondment.

After to apply the extruded coating by three-layer system, one pipe was produced with two-layer extruded system that consists of a layer of epoxy powder to provide corrosion resistance and PA 12 layer as the top coat. Some tests were perfomed in laboratory in addition to the adhesion tests. All tests were conducted on at least three samples per condition in order to validate the results.

Results e discussions

Table 1 shows the material properties of the three-layer polyamide 12 extruded system results comparing the requirements established as per ABNT 15221 parts 1 and 2, and ISO 21809. It can be seen that system using PA 12 has much higher properties to the criteria defined by standards for systems using polyethylene or polypropylene as a top coat. The adhesive layer is commonly used in three layers systems to promote adhesion between the epoxy powder and top coat layers. In the case of extrusion of polyamide 12, an adhesive based on ethylene was used, but polyamide is also compatible with adhesives propylene basis. Furthermore, the polyamide showed excellent adherence to the FBE without using adhesive as shown in Table 2. At the steel tubes with the two layers with FBE and PA 12 we could not perform the peel test like it is shown before. The adhesion between the PA 12 and the FBE is better than the adhesion between FBE layer and the steel tube. In Figure 1 is shown the sample of peel testing for three-layer system evidencing the failure in the adhesive layer. Unfortunately in two layer system was not be possible measure because the tensile samples broke during the peel test very fast , even heating the area of the steel pipe at 80°C as shown in Figure 2. The reason is the very brittle epoxy layer on the PA 12 layer which initiate by the bending and stretching a crack.

The polyamide 12 presented excellent impact resistance. Tests were performed at 0 ° C and 60°C in both extrusion systems, and tests at -20 ° C in the two-layer system. After testing, all samples were inspected by holiday detector and no failure was found, it means, no exposure of the steel tube as shown in Figure 3.

The bending tests also showed the excellent resistance of systems using PA 12 as top coat. Tests were performed at 0 ° C in both extrusion systems, and tests at -20 ° C in the two-layer system. The material did not have failure as shown in Figure 4.

Table 1 - Performance properties of PA 12 encasement application in three-layer extruded system according ABNT NBR 15221

Properties	Test method	Unit	Criteria for PE as defined on ABNT 15221-1	Criteria for PP as defined on ABNT 15221-2	Results
Total thickness	ABNT 15221	mm	Min. 1,6	Min. 1,6	2,1
Polyamide thickness	ABNT 15221	mm	-	-	1,547
Pull-Off at 23°C	ASTM D4541	MPa	Min. 17	Min. 17	25,24
Holiday Detector	ABNT 15221	-	no failure	no failure	no failure
Indentation 70±3 °C	ISO 21809 part 1	mm	≤ 0,3	≤ 0,4	0,11
Bending at 2,5 ^{o}/PD at 0±3 ^{o}C	ISO 21809 part 1	-	No cracks	No cracks	no cracks
Impact at 0±3 ^{o}C	ISO 21809 part 1	J/mm	not required	not required	no defects after holiday detector
Impact at 60±3 ^{o}C	ISO 21809 part 1	J/mm	Min. 7	Min. 7	no defects after holiday detector
Hot Water Soak (48hours at 80±3°C)	ISO 21809 part 1	mm	Med ≤2 Max ≤3	Med ≤2 Max ≤3	no disbondment
Oxidation Induction Time at 220°C	ASTM D3895 or ISO 11357-1and6	minutes	Min. 10	Min. 40	no oxidation after 220 minutes
Peel Strength at min. of 23^{o}C (25mm width strips)	ISO 21809 part 1	N/mm	Min. 15	Min. 20	637
Peel Strength at 80±3°C (25mm width strips)	ISO 21809 part 1	N/mm	Min. 3	Min. 4	309
Cathodic disbondment (measured from edge) 24h/65±°C/-3,5 V	ISO 21809 part 1	mm	≤ 5	≤ 5	1,21
Cathodic disbondment (measured from edge) 28days/23±3°C/-1,5 V	ISO 21809 part 1	mm	≤ 7	≤ 7	3,25
Cathodic disbondment (measured from edge) 28days/80±3°C/-1,5 V	ISO 21809 part 1	mm	≤15	≤15	3,64

Table 2 - Performance properties of PA 12 encasement application in two-layer extruded system

Properties	Test method	Unit	Results
Total thickness	ABNT 15221	mm	1,822
Holiday Detector	ABNT 15221	-	no failure
Impact at -20±3 ^{o}C	ISO 21809 part 1	J/mm	no defects after holiday detector
Impact at 0±3 ^{o}C	ISO 21809 part 1	J/mm	no defects after holiday detector
Impact at 60±3 ^{o}C	ISO 21809 part 1	J/mm	no defects after holiday detector
Hot Water Soak (48hours at 80±3°C)	ISO 21809 part 1	mm	no disbondment
Bending at 2,5 ^{o}/PD at 0±3 ^{o}C	ISO 21809 part 1	-	no cracks
Bending at 2,5 ^{o}/PD at -20±3 ^{o}C	ISO 21809 part 1	-	no cracks
Cathodic disbondment (measured from edge) 28days/(23±3) ^{o}C/-1,5 V	ISO 21809 part 1	mm	4,52
Cathodic disbondment (measured from edge) 28days/(80±3) ^{o}C/-1,5 V	ISO 21809 part 1	mm	4,17

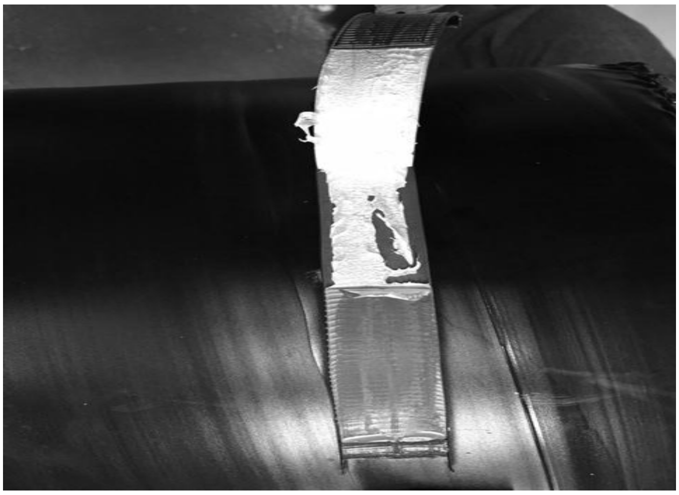

Figure 1 – Peel strength testing in pipeline with three-layer extruded system evidencing the failure in the adhesive layer

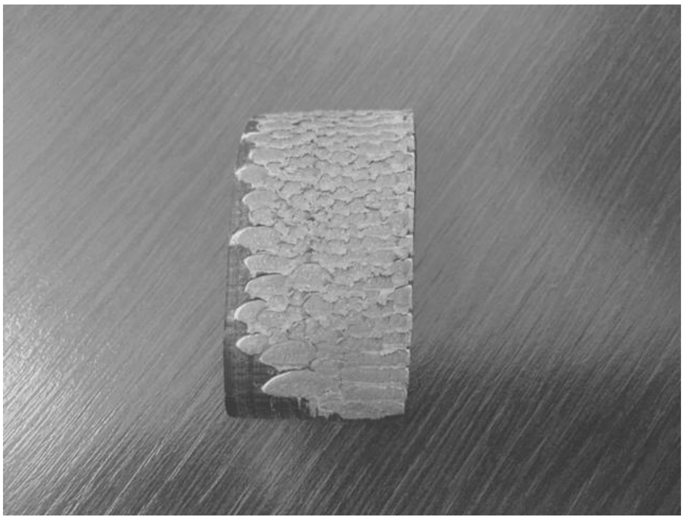

Figure 2 – Attempt peel strength testing in pipeline with two-layer extruded system after heating at 80°C. It was not be possible to measure

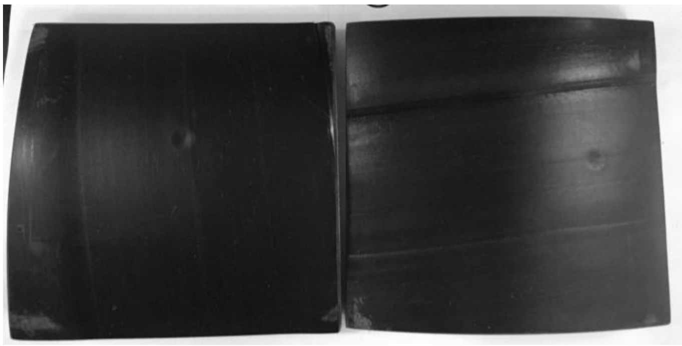

Figure 3 – Impact testing at -20°C in two-layer extruded system. No failure after holiday detector inspection

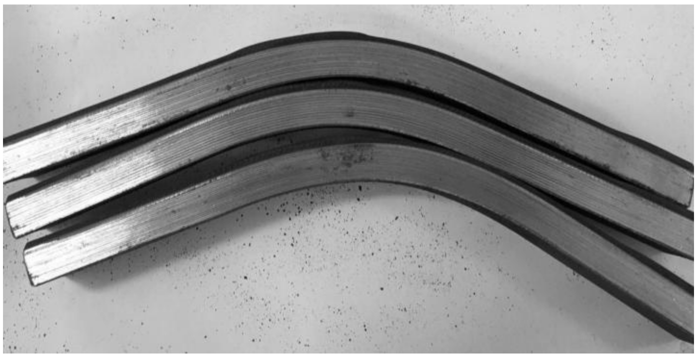

Figure 4 – Bending testing at -20°C in two-layer extruded system. No failure

Conclusion

Surface preparation and application temperature are the most important areas in which are to be carefully monitored in order to achieve proper adhesion for extruded coating system. The initial steel temperature has to be carefully examined to verify how this will affect the final cure (%) of the FBE. The initial application temperature has to be selected after evaluating the pipe size, wall thickness, line speed, polymer properties and type of extruder screw.

Polyamide 12 is a new material for extruded coatings for steel pipes protection, especially for sophisticated applications as Horizontal Directional Drilling (HDD) method with percussive impact; Soil displacement technique with non-steerable hammers; Dynamic ramming technique with non-steered ramming machines; and Ploughing/Plowing method.

For both extruded systems (two-layer and three-layer), polyamide 12 showed excellent results. It has high penetration, abrasion, adherence and impact resistance. There is less moisture permeation, which offers better disbondment resistance leading to life-time extension of pipe protection and minimize environmental risks. For two-layer extruded system, there are cost and production advantages since we can eliminate the adhesive layer decreasing final cost and further removing a variable of production process.

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