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Comparison and Study of Coating Properties of Three-layer Polyethylene, Polyurethane and Fusion Bonded Epoxy for Pipelines

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Abstract

To reduce corrosion, choosing proper coating for the outer surface of oil and gas transportation pipelines is considered the most important part in developing a protection system. The issue of cathodic disbondment is one of the problems of pipeline coatings which is caused by impressed cathodic current and generation of alkali environment at the coating-metal interface and result in coating disbondment. In this research, three coating types including, 3-layer polyethylene, polyurethane, and dual fusion bond epoxy powder are investigated and their physical, chemical, and mechanical properties are studied. The results of cathodic disbondment with simulating long-term working conditions provide an appropriate view on coatings behavior at long-term service exposure. Coatings advantage in different properties such as surface adhesion to sublayer and impact resistance are investigated using mechanical tests results. Hardness test results showed that sample hardness with dual fusion bond epoxy powder coating compared to samples with polyurethane and 3-layer polyethylene coatings is 14% and 40% higher, respectively. Impact and holiday test on three coating also showed an acceptable level of resistance to external factors. Performing cathodic disbondment test at ambient and high temperature showed that increasing temperature has a direct influence on increasing coatings disbondment radius. 4.49 mm lowest disbondment radius was observed on 3-layer polyethylene coating due to its intrinsic nature and high thickness.

Keywords: Pipeline Coatings, Cathodic Disbondment Test, Dual Fusion Bonded Epoxy, 3-Layer Polyethylene, Polyurethane.

INTRODUCTION

Selection, application, and inspection of pipeline coatings require a high degree of precision due to the variety of coatings, preparation methods and application conditions of the pipes. Corrosion protection of pipelines is usually carried out by corrosion protection and cathodic protection systems as a protective supplement due to the presence of areas where the coating is weak. The coating provides an inactive protection layer by providing a continuous, uniform, insulating layer, and preferably non-permeable layer, relative to water. This layer protects metal during storage, transportation, pipe laying in the soil and servicing. Pipelines are economic and conveyance services of each country and have strategic importance.

In this research, three coating types including, 3-layer polyethylene, polyurethane, and dual fusion bond epoxy powder are investigated and their physical, chemical, and mechanical properties are studied. For this purpose, a cathodic separation test was used to measure the segregated area for each coating and compare them with each other. To determine the mechanical properties of the coatings, the impact, hardness and adhesion tests were performed. The interface between the coatings and the underlying substrate and the underlying coating was investigated in a cathodic separation test by an optical microscope and scanning electron microscope.

EXPERIMENTAL

The thickness of the coating was measured according to ASTM D7091 standard [1]. The cathodic separation test was carried out in accordance with the ISO 21809 standard [2] at two different temperatures to evaluate the strength of the coatings against the alkaline environment. Non-consumable graphite electrodes were used as reference electrode. The samples were subjected to -1.5 volt cathodic potential for 28 days in sodium chloride 3% NaCl electrolyte and at ambient temperature (23±2°C) and high temperature (45±2°C). The adhesion strength of the three coatings was measured according to ASTM D4541 standard [3]. For high-temperature measurement, samples were placed at 45°C for one week at ambient temperature, then exited and tested. In order to evaluate the adhesion of the three-layer PE polyethylene coating the peel test performed according to IGS-E-Tp-010 standard [4], and the force necessary to separate the three-layer coating was measured. For this purpose, a pulling device is used that can record the force to separate the coating. In order to evaluate the hardness of the coatings, the Shore D hardness test was performed according to the standard ASTM D2240 [5] on three-layer polyethylene coatings, polyurethane and dual fusion bonded epoxy. The impact strength of the coatings was measured in accordance with EN 10290 [6] by weight drop method on the surface of the coating.

RESULTS AND DISCUSSIONS

According to the hardness of the sample, the dual fusion bonded epoxy, polyurethane, and three-layer polyethylene coating have hardnesses of 80, 70, and 57 respectively. As a result, the dual fusion bonded epoxy against abrasive agents has a better resistance than other coatings. Protective coatings should be well-worn to ensure good wear and tear resistance. According to the impact test results, the impact

resistance of all coatings is above 47 Jules. According to the Continuity test, there was no cracks, voids or defects caused by the impact of weights on the surface of the coating. As shown in Figure 1 (a), dual fusion bonded epoxy (DBFE) showed that with a maximum stress 20.11 MPa aluminum chip was not separated from the coating surface. Also, by performing a test on a polyurethane coating (PU), the maximum stress of the device, 20.24 MPa, could not separate the aluminum chips from the coating surface. Therefore, the adhesion of dual fusion bonded epoxy and polyurethane fusion bond is more than the maximum stress level.

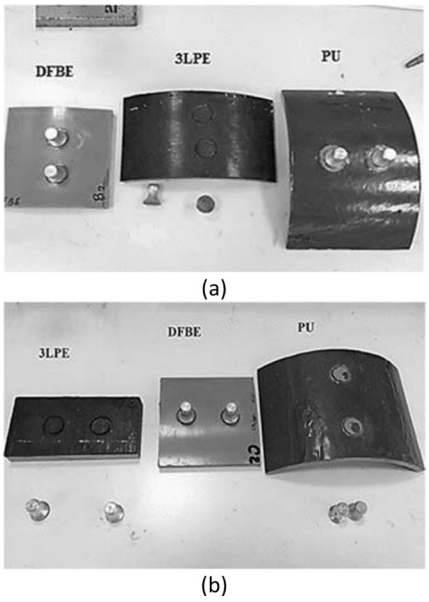

Figure 1: a) Samples were tested after the adhesion test at ambient temperature, b) After testing the adhesion test at 45 °C.

As shown in Figure 1 (b), only dual fusion bonded epoxy can maintain its adhesion strength at high temperatures. According to the Figure 2, the lowest level of separation is related to the three-layer polyethylene coating and the highest amount is related to the polyurethane coating. According to the results of the cathodic separation test in high temperature, the increase in temperature increases the radius of cathodic separation.

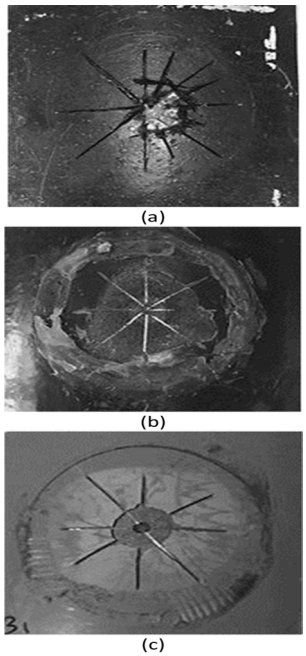

Figure 2: Samples of (a) three-layer polyethylene, (b) polyurethane and (c) dual fusion bonded epoxy after cathodic separation test at ambient temperature.

Conclusions

In this research, the properties of three-layer polyethylene coating, polyurethane, and dual fusion bonded epoxy have been investigated. The results of this research are:

- The hardness of the dual fusion bonded epoxy is higher than three-layer polyethylene coating and polyurethane coatings. The results of the impact and continuity test on the three coatings showed that all three coatings had acceptable resistance to external factors.
- The adhesive strength of the coatings at ambient temperature and 45°C, which was considered as a comparative method, indicates the superiority of the dual fusion bonded epoxy and polyurethane to the three-layer polyethylene coating. By increasing the temperature, unlike the stability of dual fusion bonded epoxy coating, the polyurethane bond

strength has reached half its strength at ambient temperature.

- The results of the cathodic separation test at ambient temperature showed that the lowest separation radius was related to a three-layer polyethylene coating, and the most separation was made of the polyurethane coating. Performing this test at high temperatures showed that the temperature increase had a direct effect on increasing the separation radius of the coatings.

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