Optimization of Coating for Austenitic Stainless Steel Pipeline in Buried, Above-ground and Splashed Condition+

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ABSTRACT

The petrochemical products are transported via austenitic stainless steel pipelines to keep the product purity. Pipelines are installed mostly buried and are marginally above-ground and splashed conditions. Austenitic stainless steel resists dry corrosion due to the formation of a chromium oxide passive film in atmospheric exposure. But an uncoated austenitic stainless steel pipeline buried in soil is doubtful because soil resistivity may be low enough due to the presence of water with chloride salts and deficient in oxygen. Passive film may then get attacked locally by such corrosive soil resulting in numerous pitting on pipe surface. As localized pitting corrosion penetrates rapidly, there is every likelihood that it will perforate pipeline within a short time without significant weight loss of metal. It is, therefore, important and necessary to protect external surfaces of austenitic stainless steel pipelines from soil corrosion. Application of protective coatings to external surfaces of austenitic stainless steel pipelines is found to be appropriate in the first place for primary protection of buried pipelines to dispatch products economically and safely to distant places.

Available literature and research papers have shown pitting corrosion of austenitic stainless steel structures in marine environment and corrosion under insulation (CUI). Metallic coatings or polymeric coatings have been studied by the researchers to protect austenitic stainless steel structures in these environments. But suitable coatings for austenitic stainless steel structures buried in soil are found to be lacking. There is an opportunity to study this issue thoroughly.

To address this issue, SS316L pipes of 4-inch in diameters have been selected in the present study. Solution-annealed SS316 with low carbon (i.e., SS316L grade) contains molybdenum (Mo) and has superior corrosion resistance against aquatic soils than other usual austenitic stainless steel grades. Six external polymeric coatings commonly used for buried or submerged carbon steel pipelines in the petroleum, petrochemical and natural gas industries have been chosen for SS316L pipelines. The polymeric coatings are 3-Layer Poly-Ethylene (3LPE), 3-Ply/2-Ply Cold-Applied Tape (3p-2p CAT), Polyurethane (PU), Visco Elastic (VE) Polyolefin, Liquid Epoxy (LE), Heat Shrink Sleeve (HSS).

In the beginning of the research work, the characterization of SS316L pipes have been performed by chemical and mechanical tests, microstructural examination, cyclic potentiodynamic polarization in 3.5% NaCl solution, pitting corrosion in 6% $FeCl_3$ solution. After preparing the external surfaces of SS316L pipes by fused Al_2O_3 fine particles, each type of coating has been applied separately to each SS316L pipe. The samples extracted from the coated SS316L pipes have been subjected to relevant tests for SS316L pipeline in buried and splashed conditions. As no coating is needed for SS316L pipeline in above-ground condition under atmospheric exposure, still one coating has been selected for mechanical testing.

For SS316L pipeline in buried condition, the samples have been subjected to relevant tests such as thickness measurement, holiday detection, Shore-D hardness measurement, impact resistance, indentation resistance in thermostatically controlled chamber under a load of 2.5 kg for 24 hours, water absorption in distilled water for 28 days, cathodic disbondment in 3% NaCl solution for 28 days, peel strength at 23^0C & 50-60^0C, pull-off adhesion strength at 23^0C & 50-60^0C, hot tap water immersion in a heated vessel at 50-60^0C for 100 days, specific electrical insulation resistance in 0.1 mol/litre of NaCl solution for 100 days applying a DC voltage of 100V, electrochemical impedance spectroscopy in 3.5% NaCl solution for 14 days with an applied AC voltage of 100 mV_{rms} in the frequency range from 100 kHz to 10 mHz.

For SS316L pipeline in above-ground condition, LE coating has been applied to SS316L plate samples. The samples have been subjected to the Taber abrasion resistance test under abrading C-17 wheels for a load of 1000g on each wheel for 1000 cycles of abrasion.

For SS316L pipeline in splashed condition, the virgin coatings and the coatings exposed to salt spray environments in 5% NaCl solution at 35^0C in the pH range from 6.5 to 7.2 for 3000 hours have been subjected to Fourier Transform Infrared Spectroscopy covering the spectral range from 4000 to 500 cm^{-1} wave number and Shore-D hardness measurement.

The experimental data have been analysed for SS316L pipeline in all conditions. The best coating among six coatings and the overall rankings of the coatings are evaluated by a simplified arithmetic mean system. The best coating and the rankings of the first three coatings obtained by a simplified arithmetic mean system have been validated by a mathematical modeling.