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Full Length Article

Investigations using potentiodynamic polarization measurements, cure durability, ultra violet immovability and abrasion resistance of polyamine cured ilmenite epoxy coating for oil and gas storage steel tanks in petroleum sector

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ABSTRACT

To uphold the corrosion protection of oil and gas steel tanks in petroleum sector, different high build epoxy coating formulations cured by polyamine hardener were modified by incorporation various concentrations of processed micro-sized ilmenite particles ($FeTiO_3$) obtained by a solid phase milling process as a pigment to form a highly cross linked ilmenite epoxy adduct in three dimensional network. The lamellar shape of micro-sized ilmenite particles was emphasized by transmission electron microscopy (TEM) investigation. Flaky-like nature and the arrangement in overlapping plates of ilmenite particles were characterized by scanning electron microscopy (SEM) micrographs. The electrochemical behavior of cured ilmenite epoxy coated steel films against unmodified conventional epoxy in oil-wells formation water has been studied by potentiodynamic polarization measurements. From the obtained electrochemical results for the coated steel films it was found that, the maximum performance was exhibited at 100% treatment of the processed ilmenite ore at which the corrosion current (I_{corr}) was less than the value 15 $nA \cdot cm^{-2}$ and exhibited the highest value of the protection efficiency (η) 99%. Cure durability test was implemented for appreciation the organic solvents resistance of the investigated cured coated films to confirm their application efficiency. The recorded data ensured the improvement in cure resistance with increasing the amount (%) by weight of micro-sized ilmenite particles against softening, wrinkling and loss of adhesion in case of unmodified conventional cured epoxy. Accelerated ultra violet (UV) exposure coating test was accomplished to measure the ability of the cured coated films to resist UV weathering and sun light damage. From the obtained exposure results it was found that, there is no blistering, no rust, no cracking, no flaking and no loss in adhesion in addition to the glossy variation at 60° was from 22.9° to 21.65° in case of the cured ilmenite epoxy coated films against complete deterioration in the film properties of conventional unmodified cured epoxy. The abrasion test was performed to determine the scraping resistance of the cured coated films. The results indicated that, there is a decrease in the weight loss of the coated films as a function of abrasion resistance with increasing the loading level (%) by weight of ilmenite pigment.

1. Introduction

Metallic tanks in contact with soil and containing petroleum products must be protected from corrosion to prevent escape of the product into the environment. Epoxy coatings have been widely used to protect various steel petroleum structures from environmental attack because of its excellent chemical resistance, outstanding processability, high electrical insulating properties and strong adhesion affinity to heterogeneous materials [1,2]. The protective action in epoxy coatings was generally achieved with the use of inhibitors such as metallic pigments, metal oxides and salts at different concentrations [3]. Corrosion of metallic surfaces in oilfields has generated much concern with regard to material loss, especially in tanks, casings, tubing, pipelines, and other

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equipment. In some areas, saline environments are the main agents that lead to corrosion [4]. High quantities of produced water along with hydrocarbons in oil and gas fields continue to increase as these fields reach maturity. This water called oil-wells formation water and comes as a by-product of petroleum production. Oil-wells formation water contains a variety of dissolved organic and inorganic compounds. This water is considered the most aggressive medium in oil field operations owing primarily to the presence of large amounts of the corrosive carbon dioxide and hydrogen sulfide in addition to other corrosive salts such as chlorides and sulfates [5]. Coating systems make use of commercial micro-size pigments to modify their corrosion resistance and mechanical properties. Commercially available inorganic pigments are associated with numbers of defects. For example, problems such as reduced coating flexibility, loss of impact resistance, loss of optical transparency, inferior abrasion, scratch resistance and poor adhesion [6–8]. Attempts have been carried out to improve the anticorrosion behavior of the organic paints containing some inorganic pigments such as lamellar micaceous iron oxide (MIO) which is essentially a type of hematite, lamellar aluminum and Zn-dust [9–11].

Ilmenite is a non-toxic pigment contains titanium-iron oxide mineral with the idealized formula ($FeTiO_3$). It is a weak magnetic black or steel-gray solid. From the commercial perspective, ilmenite is the most important ore of titanium dioxide pigment. Egyptian ilmenite ore was utilized after grinding to micro-sized scale as anticorrosive pigment and mechanical property promoter for internal epoxy coating of gas transmission pipelines [12].

Epoxy resins cure quickly and easily during application at any temperature from 5 to 150 °C depending on the choice of curing agent to form a highly cross linked adduct in three dimensional network [13]. The commonly used curing agents for epoxies include polyamines, polyamides, phenolic resins, anhydrides, isocyanates and poly mercaptans [14].

The aim of this work is to modify the protective action of epoxy coating utilized for steel tanks in petroleum fields by adding different amounts of the processed ilmenite ore to replace all inorganic solids content (fillers and pigments) and prepare some novel ilmenite epoxy coating formulations. Then, studying the electrochemical behavior of these coatings on the carbon steel surface in oil-wells formation water solution was made using potentiodynamic polarization measurements. Paint qualifications are made to evaluate the coating performance properties through cure, UV and abrasion resistance tests.

2. Experimental

2.1. Materials

Epoxy resin (D. E. R 671-X75), epoxide percentage (%): 75, density at 25 °C (g/ml): 1.09, flash point (°C): 28, non-volatile content (wt/g): 78, shelf life (months): 24, was conducted from Dow Chemical Company. Benton, Color: faintly yellowish powder, Shape: amorphous powder, solubility: disperse in organic solvents, Specific gravity (g/l): 2.1, oil Absorption (g/100 gm): 35, was obtained from Chemical Partners Company. Poly amine curing agent (ipox ER2072), Color: faintly yellow, molecular formula: $C_{10} H_{22} N_2$, molecular weight (g): 170. 25, melting point (°C): 10, flash point (°C): 27, was submitted from ipox Chemicals Company. Talc was obtained from Green Egypt Company. Xylene, isopropanol, isobutanol and benzyl alcohol were used in technical grades and obtained from El-Mohandes Chemicals Company.

2.2. Egyptian ilmenite ore ($FeTiO_3$, iron titanium oxide pigment)

A large deposit of Egypt occurs in Wadi Abu Ghalaga in the South Eastern Desert. The area comprises the eastern portion of Hamata Sheet, 30 km of Red Sea and 100 km South Marsa Alam. Ilmenite was analyzed by Thermo ARL ADVANT XP-385 XRF model and its physicochemical properties are shown in Tables 1 and 2.

2.3. Preparation of the carbon steel samples and its composition

The mild carbon steel samples used in the present work were divided into specimens with dimensions 1 cm × 1 cm × 0.8 cm. The working electrode for potentiodynamic polarization measurements was embedded in epoxy resin to expose a geometrical surface area 1 cm^2 to the electrolyte. The specimens used for the cure durability and UV immovability coating tests were with dimensions 15 cm × 10 cm × 0.8 cm and those used for the abrasion resistance test were with (100 mm) square rounded corners and with 1/4 inch (6.3 mm) hole centrally located on each specimen. The specimens were mechanically polished with different types of emery paper up to grade of 80. Then, it was rinsed in acetone and double distilled water before immersion in the test solution and its chemical composition is presented in Table 3.

2.4. Test solution

The used test solution in this investigation was the associated formation water during crude oil production submitted from Qarun Petroleum Company (QPC), Egypt. The chemical composition of this water has been carried out using ionic chromatography as shown in Table 4.The specific gravity of this water was 1.109, PH (6.23), The salinity as NaCl (151,581 ppm, wt), The total alkalinity (350 ppm, wt) and the total hardness (19.321).

2.5. Methods and techniques

2.5.1. Preparation of the micro-sized ilmenite particles [$FeTiO_3$]

The micro-sized ilmenite particles were prepared by a solid-phase milling method. The Lab Testing 911Metallurgist ball mill was used to grind ilmenite cracks obtained from ilmenite quarry for 3 h in a grinding chamber to obtain the highest degree of ilmenite fineness range at micro-sized scale.

Table 1
Physical properties of Egyptian ilmenite ore.

Character	Color	Bulk density (g/cm^3)	Specific gravity	Mohs Scale of hardness	Luster	Fracture	Oil absorption gm/100 gm	Refractive Index
Result	Black	2.2	4.45	6–6.5	Metallic	Uneven	8	2.94

Table 2
XRF analysis of Egyptian ilmenite ore.

Element	Fe_2O3	TiO_2	SiO_2	MgO	CaO	MnO	Cr_2O_3	V_2O_5	ZrO_2	P_2O_5	Humidity
Result (%)	52.69	34.15	8.32	4.1	0.29	0.1	0.083	0.18	0.068	0.014	0.005

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