

Effect of Glass Flake in Anti-Corrosive Coatings for Extreme Conditions

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ABSTRACT

Glass flake reinforced epoxy coatings have been widely used for many years on substrates exposed to extremely aggressive environments (such as splash zones of offshore installations). Glass flakes with high aspect ratio (large surface area and low thickness) can be dispersed in the epoxy resin and increase the path length for the diffusion of moisture and chemical ions. Therefore, it is believed that glass flake additives are particularly useful for harsh environments. In addition, glass flake additives are also known to enhance the durability of coatings. In this article, we used different analytical tools to determine the

influence of glass flake quantity on the anti-corrosive properties of an epoxy coatings reinforced with glass flake.

Key words: Glass flake, organic coatings, barrier property, permeability, corrosion performance

INTRODUCTION

Environments in oil and gas industries are often characterized by high temperature and pressure, harsh chemicals, humidity, extreme stress cycles, radiation, and mechanical disturbances.^{1,2} These extreme conditions degrade the ability of materials to perform, thus requiring enhanced protection through application of heavy-duty anti-corrosive and chemical resistant coatings that can withstand the aggressive environment.³

Organic coatings, because of their relatively low cost and excellent barrier protection, are typically the most viable option for protecting harsh environment assets. However, even superior quality organic coatings in their pristine form allow diffusion of chemical ions, moisture, or gas to some extent as a part of their inherent nature, resulting in coating degradation.⁴ A common method to improve the performance of harsh environment organic coatings is by reinforcing the polymer matrix with fillers.⁵ The enhanced corrosion protection may be derived from either a mechanical barrier from precipitation of inert salts or electrochemical protection through galvanic or passivation mechanisms.

Glass flake is one such filler that has been used in coating industries for several years to improve the performance of epoxy coatings in highly corrosive environments.⁶ Previous research have demonstrated that the incorporation of glass flakes into organic coatings increases the resistance of the coating to chemical ions as well as moisture or gas diffusion. Glass flake particles that have high aspect ratio (large surface area and low thickness) can align themselves in the polymer matrix parallel to the substrate. This creates a more torturous pathway for the permeation of the aggressive ingredients that come in contact with the coatings and results in extension of the coating lifetime.⁷⁻⁸ In addition to reducing permeability of the coating system, many glass flakes can offer additional advantages compared to other fillers. They provide abrasion resistance, mechanical hardness, and chemical inertness and do not impart additional color into the coating. This often makes glass flake a preferred filler choice for use in development of coatings for extreme environments.

While the use of glass flake in organic coatings can be beneficial, the extent of improvement in performance of the coating system using glass flake heavily depends on several factors. These factors include shape and size distribution, aspect ratio, quantity, and critical pigment volume concentration of glass flakes in the coating system.⁶ Glass flake is also known to sometimes adversely affect adhesion properties of the coating system which can lead to failure in protecting the substrate.

Several accelerated corrosion tests are commonly used in the coatings industry to evaluate long term performance of coatings on steel substrate.⁹ However, even these accelerated tests can be fairly lengthy and take up to several months when testing for extremely harsh environments. It is therefore necessary to pre-screen the coatings using analytical tools before long term corrosion testing, especially when large sample sets are involved. Electrochemical barrier property and water vapor permeability are two commonly used analytical techniques to pre-screen corrosion performance of coatings on steel substrate.^{10,11} This is because a major source of corrosion failure in organic coatings may result from water diffusion that may transport with it several other corrosive species.

In the work described herein, the effect of glass flake amount in an epoxy coating system is studied. By establishing three glass flake loading levels in an epoxy coating system while keeping the glass flake type constant, a three-samples ladder study (10, 17.5, and 25 weight percent glass flake) was conducted.

Electron microscopy was used to confirm even distribution of glass flake in the coatings. Electrochemical impedance spectroscopy (EIS) and water vapor permeability were used to pre-screen the effect of different amounts of glass flake in the epoxy coating system studied.

EXPERIMENTAL PROCEDURE

Sample Preparation

Three epoxy based coating systems were reinforced with different quantities of the same glass flake as listed in Table 1. The glass flake loadings by weight percent in dried film were 10%, 17.5%, and 25% respectively. The pigment-to-volume ratio of all the coating were kept constant by adjusting other pigment amounts as the glass flake quantities were varied in the formulations.

Table 1
List of coating systems with % loading by weight in dried film and dry film thickness (DFT)

Coating System	% Glass Flake in dried film	DFT (mils)
A	10%	25.9±1.8
B	17.5%	27.1±0.3
C	25%	26.0±4.1

Platelet glass flake particles with a thickness of 5 ± 2 μm were used in the coating formulations. The particle size distribution based on supplier's recommendation is listed in Table 2. The glass flake was used in the formulations without any further processing.

Table 2
Particle size distribution of glass flake used in the epoxy coating

Particle Size	1700-300 (μm)	300-150 (μm)	150-45 (μm)	<45 (μm)
% of each size	<10%	>65%		<25%

Coating Application

Test samples were prepared by applying the coatings using a 50 mil drawdown bar. The coatings were allowed to cure for 14 days before tests were performed. Microscopy samples were prepared on 6" x 3" cold rolled steel (CRS) panels. Samples for electrochemistry tests were prepared on 12" x 4" CRS panels. Free films of the coatings were used for water vapor permeability test. Free films were prepared by wrapping release film on steel panels to provide a rigid support. The coating was applied using the drawdown bar on the release film. Once cured, the film was removed from the panel for the test.

Testing

Cross-sectional Field Emission Scanning Electron Microscope Imaging (FE-SEM)

The samples were prepared using a panel cutter and mounted in epoxy overnight. After curing, the mounts were ground and polished. They were then placed on aluminum stubs with carbon tape and