

Long Term Performance of Glass Flake Reinforced Polyesters - A Case Study After 35 Years Under Offshore Conditions

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ABSTRACT

The offshore Oil&Gas industry started in the early 1970's on the Norwegian Continental Shelf. Some of the first jacket installations were first applied with traditional epoxy coating systems. However, good experience with glass flake reinforced polyester coatings in the early 1980's convinced operators to apply these high build coating systems for all new structures, as well as refurbishing several existing structures during offshore maintenance campaigns. Glass flake reinforced polyester coatings have now been used for more than 35 years under offshore conditions on the Norwegian Continental Shelf. High film thickness and highly abrasion-resistant coatings have proven to be highly durable in the tidal/splash zone of offshore constructions.

Some of the first Oil&Gas offshore structures are now being decommissioned. This enables investigations on the long-term performance of coatings exposed to harsh conditions with limited access. This study presents the findings from an investigation performed on a glassflake reinforced polyester coating that was applied under offshore conditions for approx. 35 years ago. The presented results contain traditional visual inspection and adhesion testing, as well as more advanced analysis including FTIR, DMA, SEM/EDX, and EIS. The results show that there was no detected under film corrosion and the adhesion values were acceptable. Further, the analysis showed that the product has undergone some ageing, however, the barrier properties of the coating system are still excellent.

With many new offshore wind projects underway it is important that the industry provides knowledge and experience from offshore Oil&Gas to ensure long-term corrosion protection under offshore conditions to enable a sustainable service life.

Keywords: organic coatings, polyester glass flake reinforced coatings, offshore Oil&Gas, tidal zone, offshore wind

INTRODUCTION

Offshore wind farms are important contributions to the growing need for the generation of renewable energy. The number of offshore wind farms is growing, and multiple projects are under planning and construction around the world. One key element for a profitable and sustainable operation of offshore wind farms is that the installations are protected with the most cost-effective corrosion protective solution for the entire lifetime of the offshore wind farm. In practice, this means that today's projects are planned with an estimated lifetime of a minimum of 35 years without major maintenance of the corrosion protective solution. To achieve this it is instrumental that the entire lifetime cost is considered when a corrosion protective solution is selected.

The first offshore wind farms were put in operation in the North Sea in the early 2000s, and after two decades the industry has gained experience from in-service conditions related to the corrosion protective coating systems and their ability to withstand the harsh offshore conditions [1]. Especially the splash zone (tidal zone) is of concern when it comes to effective protection against corrosion. This area is exposed to cyclic conditions (wet/dry, warm/cold, high/low salinity) by tidal movement and waves, in addition to mechanically induced stresses from boat landings, waves, and floating debris. Inspections of such areas of offshore wind installations have over the years revealed cases of substantial coating degradation, premature coating failure, and corrosion despite the corrosion protective coating system had been qualified by testing following well-known industry standards for offshore coating systems. However, it is important to note that the coating system itself was deviating from what is described in NORSOK M-501 about several coating layers and dry film thickness (DFT) [2]. These cases have shown both that there is a lack of correlation between accelerated laboratory testing and field experience, and that experience from in-service conditions and track record is an important contribution for selecting the correct corrosion protective solution.

In the early 1970's the first offshore operations on Oil&Gas installations on the Norwegian Continental Shelf were starting up. After almost five decades of experience from Oil&Gas installations exposed to tough offshore conditions, including splash zone, there is a lot of knowledge to be transferred from the offshore Oil&Gas industry to the offshore wind industry operating under similar conditions. By a successful transfer of knowledge and experience the relatively new offshore wind industry can utilize the learnings on how to best protect their assets in a harsh offshore environment.

As more aged Oil&Gas installations are being decommissioned more in-depth investigations of previously inaccessible areas are becoming possible to execute. This study presents such an investigation of a glass flake reinforced polyester coating system applied in the splash zone area of a jacket structure operating on the Norwegian Continental Shelf, during an offshore maintenance campaign in the late 1980's.

CASE STUDY

The jacket structure of an aged Oil&Gas installation was decommissioned in 2019. The platform had been in service since the early 1970's and the splash zone area was first coated with what is assumed to be a traditional epoxy coating system. However, based on good experience using glass flake polyester coatings on other offshore structures during the early 1980's it was decided by the operator to apply such coating systems during offshore maintenance campaigns from the mid to late 1980's. During these maintenance campaigns, all the accessible areas of the jacket structure were abrasive blasted and two layers of glass flake reinforced polyester coating was applied. Despite non-ideal conditions for surface treatment and paint application, the glass flake polyester coating showed no significant degradation nor corrosion during the remaining lifetime of the asset until decommissioning. Hence, the splash zone area of the jacket structure did not undergo any maintenance throughout the approx. 35 years of service between application of the glass flake reinforced polyester and decommissioning.

Samples from the jacket structure were cut out during decommissioning. The sampling area was in the atmospheric area of the splash zone of the structure. Meaning that the entire time between application of the glass flake polyester coating and the end of service life, the sampled area had been exposed to harsh offshore conditions.

Experimental

A sample cut out of the jacket structure was investigated, the sample was approx. 800 mm long, 500 mm wide, and the steel thickness was approx. 50 mm. The steel was a structural carbon steel alloy, and the surface treatment

performed during offshore maintenance was by abrasive blasting. The steel substrate had been applied with a coating system comprising of two layers of glass flake reinforced unsaturated polyester coating, each layer was approx. 600 μm thick.

Visual inspection was conducted as per ISO 4628-2, ISO 4628-3, ISO 4628-4, and ISO 4628-5 [3-6].

Pull-off adhesion testing was performed as per ISO 4624 [7]. The sample was wiped off and 20 mm diameter dollies were glued onto the coating using an epoxy adhesive. After 24 hours the coating was cut around the dollies, and the dollies were pulled off vertically using a pull-off adhesion tester.

EIS measurements were performed using a potentiostat in a three-electrode setup. A glass cell was sealed against the sample using silicone sealant and filled with 5 wt% NaCl solution as an electrolyte, Figure 1. Reference and counter electrodes were Ag/AgCl (with saturated KCl solution) and graphite, respectively, while the substrate acted as the working electrode. Impedance data were obtained in the frequency range from 10 mHz to 100 kHz with an amplitude voltage of 50 mV at a constant direct current bias of -0.45 V relative to the reference electrode. The sample was conditioned for 24 and 48 hours in 5 wt% NaCl solution before measuring. All measurements and conditioning were being performed under ambient conditions at 23 °C. The collected impedance data were fitted to an equivalent electrical circuit often referred to as the Randles circuit to extract pore resistance values and for assessing any underfilm corrosion and coating degradation.

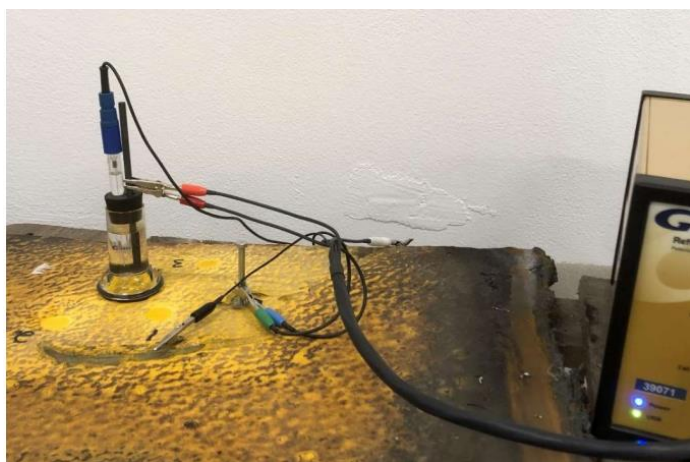


Figure 1. Three electrode setups are attached to the coated sample for EIS measurements.

Scanning electron micrographs (SEM) were collected of both the surface and cross-sections of the free paint films to investigate the microstructure and composition of the coating. Energy-dispersive X-ray spectroscopy (EDS) was used to assess the composition of the coating sample semi-quantitatively.

Dynamic mechanical analysis (DMA) was carried out on coating flakes collected from the jacket structure and a reference sample of a newly produced free coating film of the same coating product prepared and cured for 168 hours under ambient conditions in the laboratory. The coating samples were heated at a rate of 4 °C/min from - 50 °C to 175 °C, under a periodic sine wave tension with 5 μm amplitude at a frequency of 1 Hz.

Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR) was additionally conducted on both the aged and freshly prepared samples to authenticate the identity of the retrieved samples to be consistent with that of present-day glass flake reinforced polyester. The evaluation was done using a Diamond ATR from the top and bottom of the samples, both of which were done using 12 scans in the range 4000 to 450 cm^{-1} .

RESULTS AND DISCUSSION

The steel substrate was applied with a two-layered coating system comprising of 2x600 μm of glass flake reinforced unsaturated polyester coating during offshore maintenance campaigns in the late 1980's. The coating is known to