# Environmental Testing on Composites Overwrap Repairs : Effects of Curing on Durability

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### Introduction

Composite materials have been successfully used in the repair of ageing and damaged steel pipes in the offshore sectors and application of composites repair is on an upward trend due to its reliability and cost-effectiveness, which stem from the advantageous properties of composites. Nevertheless, whilst short-term reliability of composite repairs are relatively well documented, their long-term durability is less well understood. It should also be highlighted that application of the repair on-site relies heavily on the surrounding environment as well as the operator skills. In an ideal situation, it would be assumed that the application adheres completely to the guidelines. However, in reality, this is seldom achieved. The study is therefore aimed to investigate the progressive changes in behaviour and properties of the system when subjected to two differing curing conditions and consequently submerged in seawater for extended periods. Reports include materials characterization results, weight changes as well as findings from microstructural analyses using optical microscopy. Apart from general observation, the results will also be presented in the context of the number of overwrap layers.

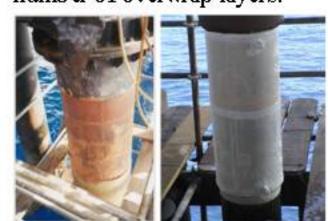


Fig. 1. Typical composites overwrap repair on an offshore riser

### **Materials and methods**

### 1.0 Specimens

Preforms of selected wrap material were bonded onto samples for environmental tests at differing curing conditions. The wrap material is of glass reinforced polyester commonly used for overwrap repair in the oil and gas industry. The materials will be subjected to environmental tests via immersion test in natural seawater, to study the moisture uptake behaviour of the repair materials. The variable of interest will be the curing conditions and the different thickness of the repair materials, namely 2-layer and 4-layer of the wrap material.

### 2.0 Specimen Preparations/Curing Regime

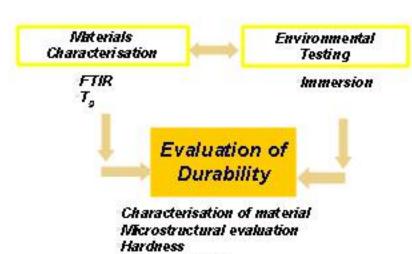
The material of interest is a chopped-strand mat isophthalic polyester based (proprietary) prepreg, and is activated by UV cure for 24 hours. Two sets of samples were prepared; cured in direct ultraviolet (UV cured) and cured in lab condition (RT cured). Preparations were performed in accordance to the suppliers' guidelines, which included applying a primer on the prepreg and hardened for an hour before applying the following layer. Final cure is considered complete after 24 hours exposure in UV. Hardness measurements are taken after 24 hour curing using Barcol Hardness test.

### 3.0 Materials Characterisation

The materials were subjected to a series of materials characterisation analysis with the aim of fingerprinting the material before and after immersion to seawater. The type of tests include Fourier Transform InfraRed (FTIR) spectroscopy, Differential Scanning Calorimetry (DSC) and microscopical examination. Microstructure of the samples are also recorded before and after exposure.

### 4.0 Environmental Test

The samples are subjected to immersion in natural seawater up to 312 hours (44 days) and is periodically evaluated at intervals of 2-3 days. The test temperature is maintained at ambient temperature.



Moisture Uptake

Fig. 2. Illustration of project flow chart summarizing experimental design.

# Results

#### 1.0 Materials Characterisation

Fingerprinting of the material revealed the presence of C=O peaks indicating that the matrix is a Polyester, with a  $T_{\rm g}$  of  $115^{\circ}{\rm C}$  (midpoint). These properties were used as reference data for comparison with the samples subjected to weathering test as mentioned before.

FTIR analysis on the unexposed samples showed that there is a difference in intensity of the spectrums of the UV-cured and RT-cured specimens. However, upon initial immersion tests, the spectrums were observed to be similar for both sets of samples. This indicates that the UV-cured sample did not undergo any change upon immersion, but the RT-cured sample had a change in the intensity and the spectrum was now similar to that of the UV-cured specimens as shown in Fig 3b. However, upon prolonged immersion (312 hours), a change was again observed in the RT-cured sample as the intensity of the spectrum had decreased as seen in Fig 3c. The UV-cured spectrum remained the same after 312 hours immersion.

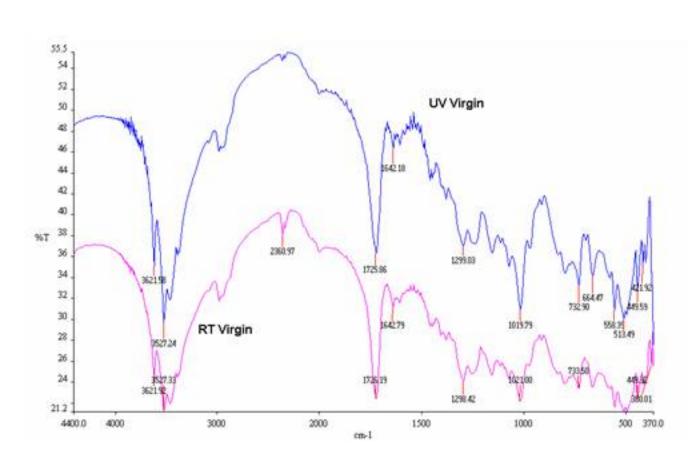


Fig 3a FTIR spectrums of virgin (unexposed) UV- and RT-cured samples

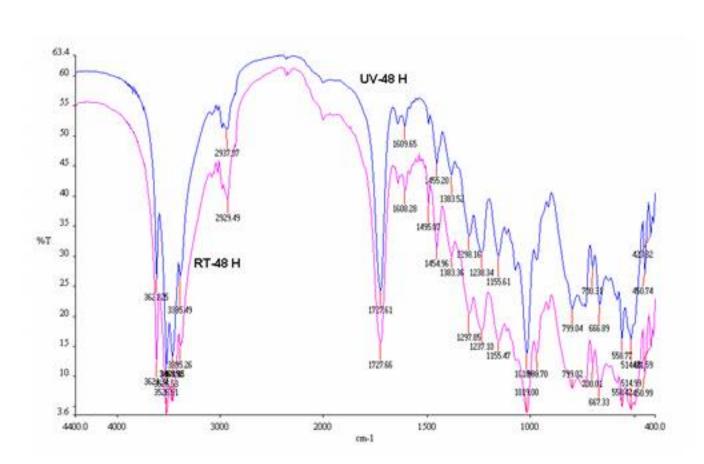


Fig 3b FTIR of the UV- and RT-Cured samples after 48 hr exposure in seawater

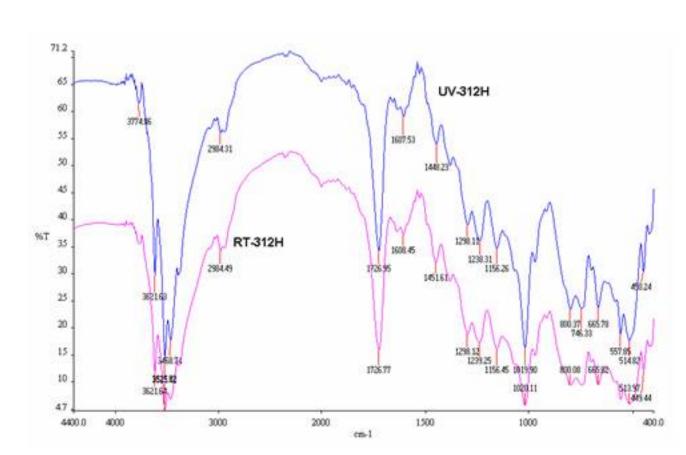


Fig 3c FTIR of the UV- and RT-Cured samples after 312 hr exposure in seawater indicated some changes between the two differently cured samples

### 2. 0 Environmental Tests

The specimens were taken out of the chamber and the weight difference were recorded after 48 hours (as shown in Table 1) up to 312 hours. Visual observation also showed no apparent change in colour of the material in both sets of samples. However, some slight material loss had been observed in the RT cured specimens as early as after 144 hour exposure as seen in Fig 4b.

The weight change of the samples were observed to be very little even after 312 hours immersion, and similar observations were recorded for both the UV-cured and the RT-cured samples as seen in the graph shown in Fig. 6.

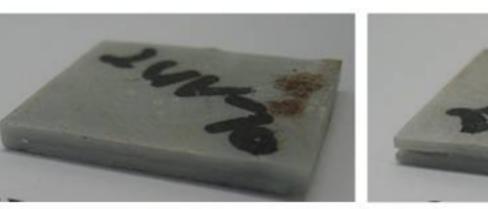


Fig 4a: 2-layer UV cured sample Fig 4b: 2-layer RT cured sample after 144 hours seawater exposure after 144 hours seawater exposure



Fig 5a: 2-layer UV cured sample after 312 hours seawater exposure after 312 hours seawater exposure

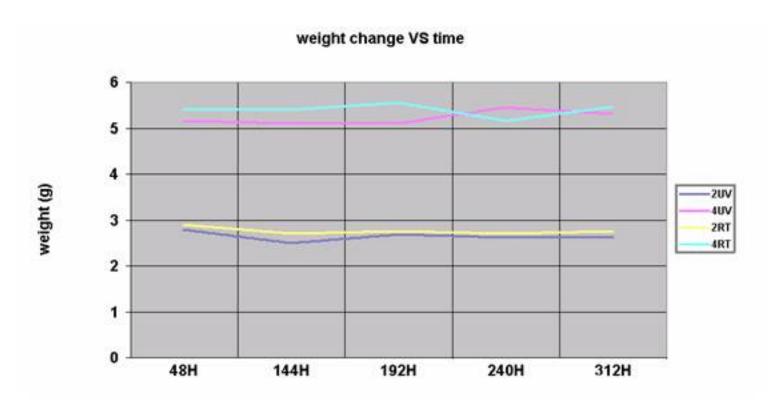


Fig 6: Weight change trend after 312 hours exposure

### 4.0 Hardness Test

The hardness values of the exposed samples revealed a similar trend whereby all samples experienced an increase in hardness values after 312 hours exposure, and this was observed both in the 2 layer samples and 4-layer samples. Figure 7 shows the trending of the hardness, whereby a increase in value is seen after 48 hours exposure onwards.

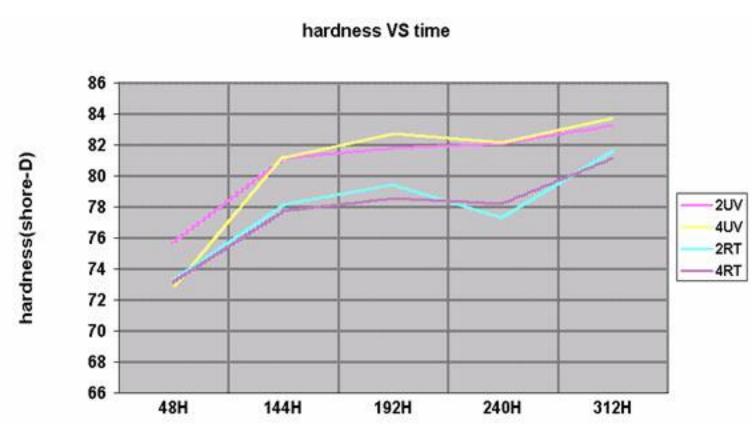


Fig 10: Hardness trend after 312 hours exposure

### 3.0 Microstructural Examination

Microscopical examination of the cross-section of the samples were taken before and after immersion, for both the RT-cured and UV-cured samples. The examination revealed that no significant change was observed in the microstructure of the samples, either in the RT-cured or the UV-cured samples, for both 2 layer and 4 layer configuration., as shown in Figures 8 and 9.

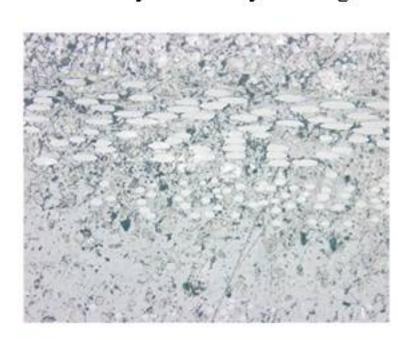


Fig 8a Micrograph of RT-cured sample before immersion (2layer) at 10x magnification



ole Fig 8b Micrograph of UV-cured sample before immersion (2layer) at 10x magnification

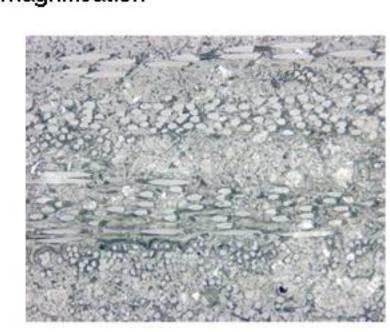
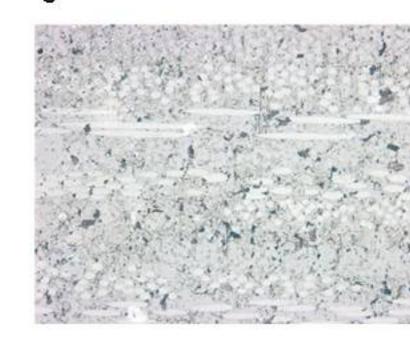


Fig 9a Micrograph of RT-cured sample after immersion (2layer) at 10x magnification



r Fig 9b Micrograph of UV-cured sample after immersion (2layer) at 10x magnification

### Conclusions

In this study, initial observations showed a difference in hardness values between the UV cured and RT cured samples. However, upon exposure to seawater, a similar trend was observed whereby an increase in hardness was noted in both sets of samples. This was interesting, as it was anticipated that the hardness would decrease after immersion in seawater due to softening of the resin. With respect to weight change, there was no significant weight increase noted, and similar behavior was observed for all samples. Microscopically, no significant changes were recorded after 312 hours immersion in seawater. An interesting observation was recorded, however, with respect to the FTIR results. There was a difference in the spectrum intensity between the unexposed RT-cured and the UV-cured sample, but upon initial exposure, the RT-cured spectrum appeared to be similar to that of the UV-cured. However, upon prolonged exposure, the RT-cured spectrum experienced another change. The UV-cured spectrum remained unchanged with exposure.

The observations gathered in this study therefore, indicates that the curing condition does have some effect on the material to some extent, although in this case, the effect may not be too evident as the exposure time may be too short to affect the material. Further studies is being recommended to look at effects after prolonged exposure and harsher environmental conditions.

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# For further information

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