Testing of Glass Fibre-reinforced Polymer Composites

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A. Introduction

A degradation study of polymer composites has been undertaken in the Southern African environment.

Why study degradation in SA ?

New equipment and materials from foreign locales are being increasingly used in Southern Africa. As the degradation of polymer composite materials is previously untested in Southern Africa, there is a need for strength data to predict the safe service life of composite structures exposed in the natural environment. As part of this study, the effectiveness of protective measures in minimising damage due to exposure to the natural environment will also be investigated.

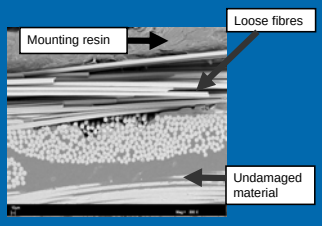
B. Natural Exposure

Six climatically different regions were identified to represent the entire range of climates experienced within South Africa. The climates range from hot and dry to warm and humid, and include a tropical climate. Two types of aircraft certified epoxy laminates, a vinylester laminate and two types of polyester laminates have been manufactured for exposure. These laminates are representative of the most common types of polymer composites used in the local industry.

Laminates were mounted on an inclined panel at each test location. The inclined panels, known as latitude racks, are used to maximise the incident solar irradiation onto the specimens. The angle of inclination of all exposure racks is set at 30° for simplicity. Protective measures, e.g. shade cloth protection, paint and gelcoats are also being investigated to compare various simple, low cost methods of effectively reducing the rate of degradation of mechanical properties.

C. Testing

1. Scanning Electron Microscopy (SEM)

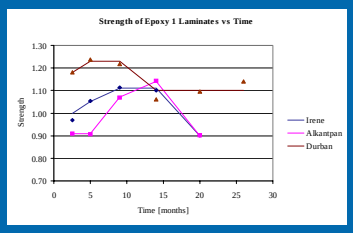


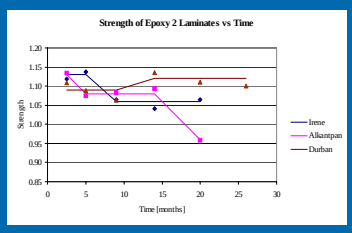
An examination of exposed specimens manufactured from Epoxy 1 prepreg reveals matrix erosion resulting in loose reinforcing fibres visible at the surface. The matrix appears to have eroded to a depth of ½ the thickness of the first layer of reinforcement after 9 months of exposure.

2. Mechanical Testing (Flexure)

Flexure tests according to ASTM D 790M were performed to determine reduction in ultimate strength due to exposure. Test specimens were prepared from three exposed panels of each material to ensure the test results were representative of the strength of the exposed laminates.

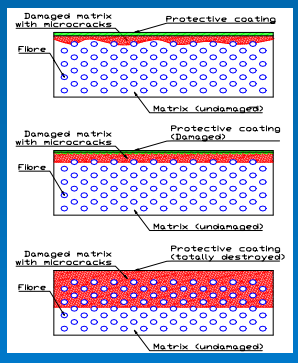
3. Test Results





Flexure test results, illustrated above, are normalised by dividing the failure strength of the exposed laminates at specific time intervals by the original unexposed laminate strength. Epoxy 1 laminates experienced a measurable increase followed by a decrease in strength. A similar trend of increased strength during initial stages of exposure was observed on Epoxy 2 laminates manufactured by wet lay-up. The increase in strength due to exposure is thought to be due to post-curing of unreacted polymer. Subsequent decreases in strength may be attributed to damage incurred on the laminates due to exposure.

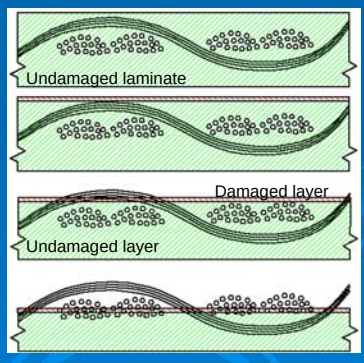
D. Modeling



First Model

The first model developed was based on a Functionally Graded Material (FGM) approach with a damaged layer upon an underlying undamaged layer. Damage was assumed to be primarily in the form of microcracks that would propagate with time into the laminate. The mechanical properties of the damaged layer would be determined using fracture mechanics. Bulk material properties would be obtained by combining the properties of both the damaged and undamaged layers.

A second model was proposed to describe the degradation observed based on test observations. This model consists of a damaged layer of constant thickness on the surface of undamaged material. As the damaged layer progresses into the material, material is lost from the surface thereby resulting in a damaged layer of constant thickness. Damage at the surface would primarily be due to microcracks in an embrittled matrix.



Second Model

E. Conclusion

A study has been undertaken to determine the modes and rate of degradation of polymer composites due to exposure in the Southern African climate. Both protected and unprotected laminates have been exposed in different climates throughout the region. Specimens are removed bi-annually for examination and testing. Initial increases in strength measured may be due to post-curing and subsequent decreases in strength due to damage incurred. By comparing observations on the exposed laminates after specific exposure intervals, the predominant degradation factors will be identified. Weather data is being recorded to characterise the environment. The strength test data will be used to verify the mathematical model which may be used to predict safe service life of polymer composite structures. A second mathematical model has been proposed to describe the degradation based on observations of exposed laminates. In addition, accelerated exposure tests are being performed in the hope of establishing a correlation between natural and accelerated exposure tests.

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