The Influence of Environmentally Assisted Aging on the Degradation of a Carbon-Epoxy Composite

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Project Aim

To evaluate the potential changes in the mechanical properties of a carbon-epoxy composite when subjected to a range of environmental conditions of different time periods.

Manufacturing & Methods

The composite laminate was manufactured using twill carbon fibre cloth infused with IN2 epoxy resin | *Figure 1*.

- These constituent materials were infused using a resin infusion under flexible tooling (RIFT) manufacturing method.
- This laminate was left under a vacuum pressure of 10.1 mbar for 48 hours to ensure maximum infusion.
- Specimens were then cut from this laminate sheet using a Tyslide diamond saw.

Figure 1: Manufactured RIFT Laminate Panel

After the specimens were cut, they were exposed to three separate environments. These environments were chosen using relevant literature, thus defining the final exposure conditions that the specimens were subject too. The final exposure conditions were as followed:

- Ultra-Violet Radiation (UV) at a range of 320 – 420 nm | (Lu, *et al.*, 2018)
- Moisture at 100% relative humidity (RH) | (Zheng & Morgan, 1993)
- Sub-Zero Temperature at [<-40°C] | (Zaoutsos & Zilidou, 2017)

Specimens were tested using ISO standard methods at predetermined intervals, these intervals are shown in the table below. The specimens were tested using a range of equipment:

- Interlaminate Shear Strength Test (ILSS) | *Figure 2.*
- 3-point Flexural Test | *Figure 3.*
- Vickers Hardness Test.
- 6 Decimal Place (DP) Scales.

Testing Schedule		
Day 1	Day 35	Day 112
16/11/2020	14/12/2020	08/03/2021
Initial Exposure	1st Removal	2nd Removal

Figure 2: ILSS Testing Equipment

Figure 3: 3-point Flexural Testing Equipment

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Results

Mass Variation: All specimens witnessed a change in mass over the 16-week period, it was concluded that environmental exposure had caused this. This increase was most notable in specimens that were exposed to moisture, where they witnessed a 3.68% mass increase over the 16-week period compared to the mass increase in UV of 1.00%.

3-Point Flexural Specimens: The results obtained for the flexural specimens compares the change in ultimate tensile strength of the composite over the 16-week period, this data was compared to dry baseline samples. As shown in | *Figure 4* | the dry specimens ultimate tensile strength (UTS) increased by 12.2% over the 16-week period, whereas the moisture specimens UTS decreased by 26.2%

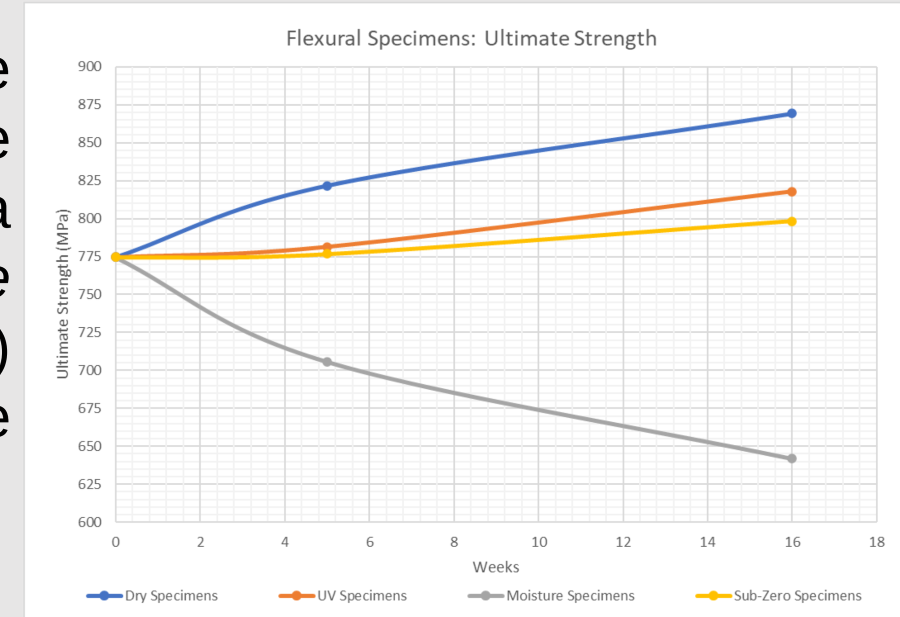

Figure 4: Recorded Ultimate Tensile Strength for 3-point Flexural Specimens

ILSS Specimens: The ILSS specimens followed the same formation as the flexural specimens, increasing the overall reliability of the results | *Figure 5* |. Furthermore, the results obtained in this report followed that of relevant literature, when compared to (Zaoutsos & Zilidou, 2017), a difference of 5% in UTS was noticed.

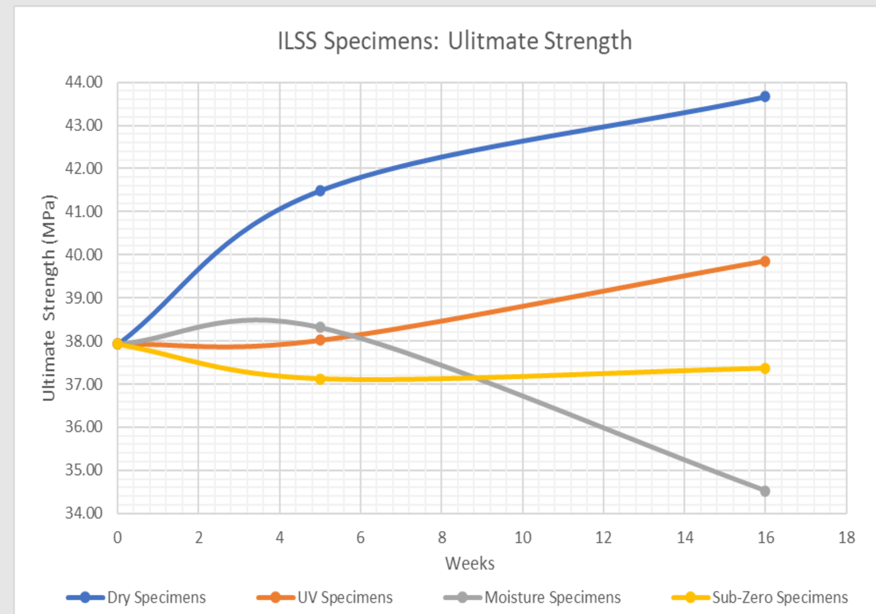

Figure 5: Recorded Ultimate Tensile Strength for ILSS Specimens

Vickers Hardness Test: The results from the Vickers hardness test varied, with UV specimens increasing in hardness, and moisture specimens decreasing in hardness over time. It was concluded that these changes were due to photo-oxidative reactions in the UV specimens, increasing the brittleness of the material, and plasticization in the moisture specimens increasing the over flexibility of the specimens.

References:

Lu, T., Solis-Ramos, E., Yi, Y. & Kumosa, M., 2018. UV degradation model for polymers and polymer matrix composites. *Polymer Degradation and Stability,* Volume 154, pp. 203 - 210.

Zaoutsos, S. P. & Zilidou, M. C., 2017. Influence of extreme low temperature conditions on the dynamic mechanical properties of carbon fibre reinforced polymers. *Materials Science and Engineering,* (276).

Zheng, Q. & Morgan, R. J., 1993. Synergistic Thermal-Moisture Damage Mechanism of Epoxies and Their Carbon Fibre Composites. *Composite Materials,* 27(15), pp. 1465-1478.

Conclusion & Further Recommendations

- This project has shown that exposure to the three environments has cause significant degradation in the mechanical properties of the carbon-epoxy specimens, when compared to unexposed specimens.
- It is recommended that increasing the exposure time, number of experiments and rate of testing will increase the accuracy of data, thus increase the reliability of this project.
- Access to a wider range of equipment will aid in understanding the microscopic changes in the material structure.

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