



Thermally Induced Effects on Carbon Fibre
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Introduction

(McBeath, 2015) discusses in his 2015 book, how motorsport manufacturers explore the limits of the regulations to achieve aerodynamic benefits, with certain benefits being achieved through thermal input. As such it was decided to explore the principle of exposing carbon fiber to varying heat treatment to determine two separate factors:

- The extent of expansion as a result of heating and whether an aerodynamic benefit within a brake duct application is achievable.
- How repeated thermal exposure effects the structural properties of carbon fiber.

For all investigations within this project MTC400 T800 UD carbon fiber was used.

Deformation Study

Test Procedure

Initially tests using an aluminium block and design studio test with bi-metallic strips were carried out to validate both the test procedure and computer software.

280mm x 280mm square test samples of carbon fibre were measured at ambient before being heated to 100° C where the dimension were measured again. Measurements were taken using a digital height gauge, shown in Figure 1. It is worth noting the test procedure does not account for the test piece cooling between removal from the autoclave and measurement of dimensions.



Figure 1: Photo of the measurement process used when recording the dimensions of the carbon fibre before and after the test sample has been exposed to heat (Lillicrap, 2019)

Summary of Outcomes

The results of the testing are shown in table 1, The test results were used to determine the coefficient of thermal expansion. The vast variation in values is a result of errors within the test procedure due to it not accounting for the level of cooling that the carbon fiber experiences. As evident from the results, the deflection is not large enough to significantly affect the aerodynamics.

TABLE 1: Achievable Deformation		
	Deformation	
	Fiber	Matrix
Test 1	0.016	0.273
Repeat	0.026	0.143
Autodesk	0.012	0.300

Thermal Cycling Study

Test Procedure

Test samples were exposed to 0, 10, 20, 50 and 100 cycles. One cycle meant that test samples were placed into the autoclave at ambient and heated to 100°C. Each sample was held at either temperature for 20 minutes. All test samples returned to ambient before another cycle was initiated. After cycling 20 samples of the 0, 50 and 100 cycled test samples were subject to tensile testing as well as 10 of the 10 and 20 cycled pieces. 8 of the 0, 50 and 100 test samples were also subject to non destructive testing.

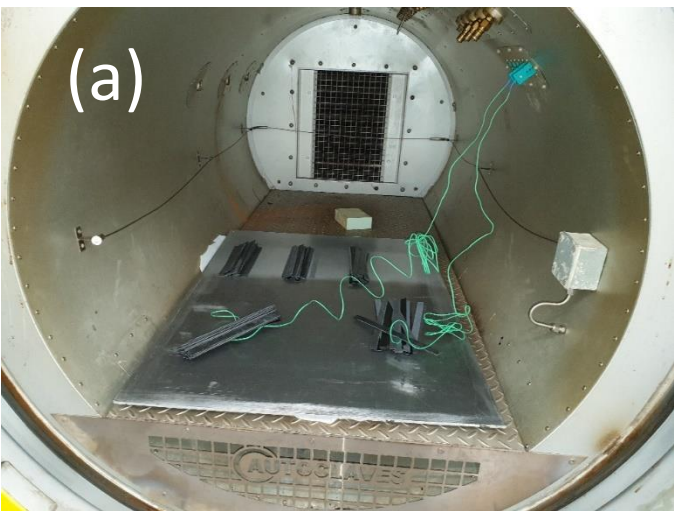


Figure 2: (a) Test Samples with Thermocouples Attached in Autoclave for the thermal cycling tests. (b) Denison Tensile Machine used for Tensile Testing

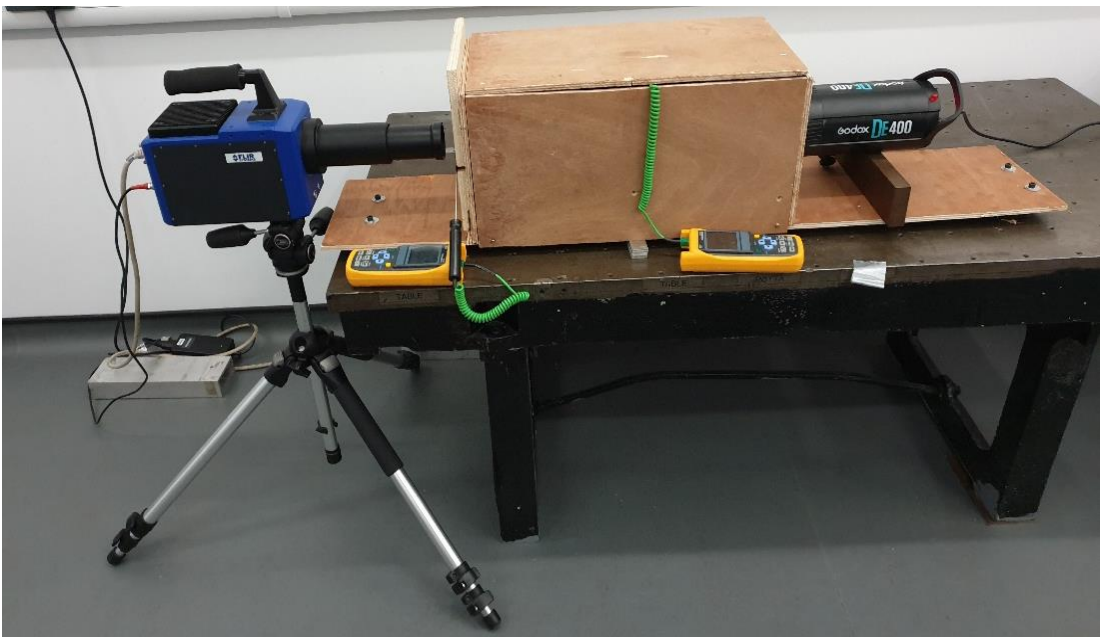


Figure 3: Non-destructive Test Procedure using Thermography Camera

Summary of Outcomes

As shown by figures 4 and 5 the results of the testing show that after prolonged heat treatment (50+ cycles) the test samples begin to degrade which matches with research by (Daguang, et al., 2013) and (Ghasemi & Moradi, 2017). However issues with the tensile test equipment meant that a true value of the change experienced by the test samples cannot be determined.

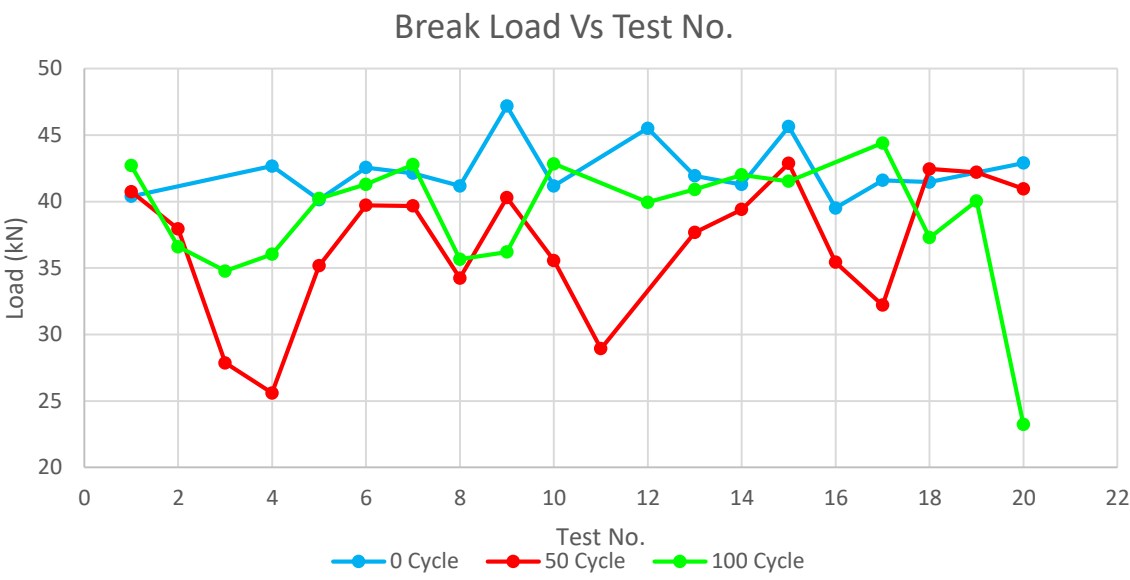


Figure 3: Graph of Varying Break Loads for 0, 50 and 100 Cycle Tensile Tests

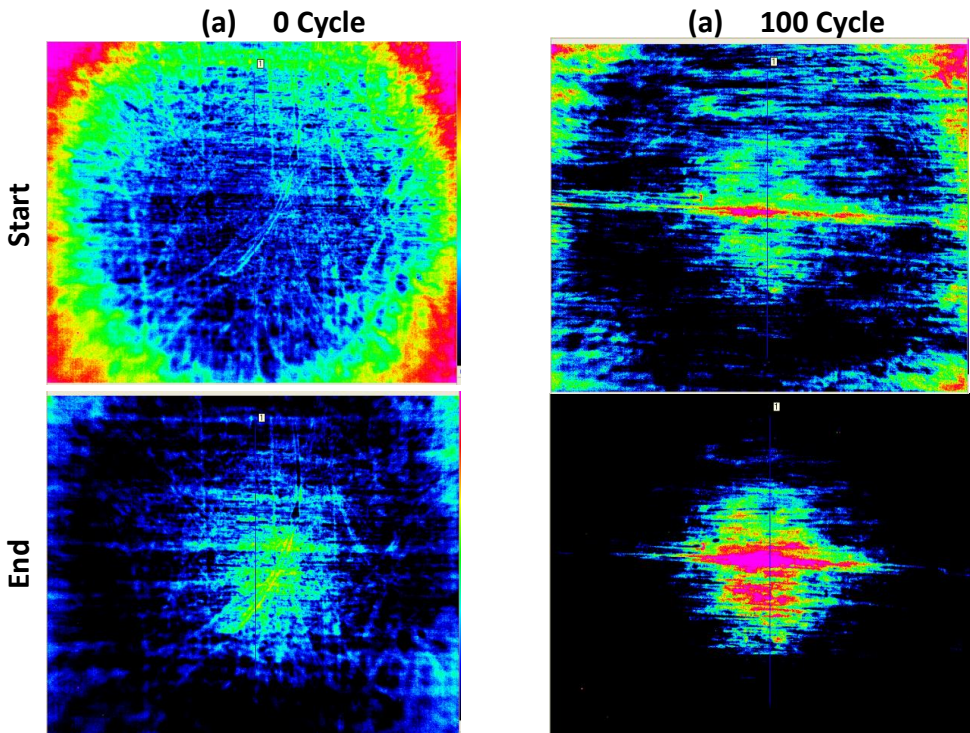


Figure 4: Example Results of Non-Destructive Tests. Comparison of 0 and 100 cycle results with areas of intense heat shown in bright pink.

The results can be further summarized to two main outcomes:

- The tensile test prove that the test samples become weaker however it becomes increasingly difficult to determine an exact break load with 50 and 100 cycled test samples as such the predictability of the test samples has decreased.
- The non-destructive testing showed that deterioration of the epoxy only became evident after 100 cycles where microvoids and cracks began to become apparent.

Discussion of Project

The results of both thermal studies proved that subjecting the carbon fiber test samples to thermal treatment can cause variation in the test samples. In terms of deformation the values achieved are not large enough nor is it viable to be utilized for an aerodynamic benefit. Further to this, thermally cycling the test samples does greatly impact the mechanical and structural properties of the carbon fibre although the exact effects are yet to be conclusively determined.

Acknowledgements

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References

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Ghasemi, A. R. & Moradi, M., 2017. Effect of Thermal Cycling and Open-hole Size on Mechanical Properties of Polymer Matrix Composites. *Polymer Testing*, Volume 59, pp. 20-28.

Daguang, L. et al., 2013. Effect of thermal cycling on the mechanical properties of Cf/Al composites. *Materials Science & Engineering A*, Issue 586, pp. 330-337.