CTE and Tg Measurements of 360 tooling block.

for

CFP Composites Ltd.

AS4615

05 December 2019

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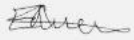
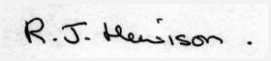
Technical review	**Elaine Arnold**	
Authorised	**Rob Hewison**	

Authorised distribution: CFP Composites Ltd.

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The AMRC has prepared this report on behalf of CFP Composites Ltd.

Document revision history

Revision	Date of issue	Reason for revision or original issue
DRAFT01	03 December 2019	First draft
DRAFT02	04 December 2019	Technical review
DRAFT03	05 December 2019	Authoriser review
01	05 December 2019	First original issue

Executive summary

CFP Composites Ltd have just launched a new tooling block material. This is a novel product being marketed as “360” made up of a nylon matrix reinforced with randomly orientated short carbon fibres. They are selling this product as a block material specifically into the composites tooling market. It allows for tools and patterns to be machined directly from this block to give a low CTE, high temperature capable tool. Compared to conventional laminated composite tooling this removes many of the process steps required. Compared to Invar metallic tooling, it is likely to offer a cheaper, shorter lead time tooling solution. CFP Composites Ltd approached The AMRC to see if we could measure some glass transition (Tg) and coefficient of thermal expansion (CTE) values for the 360 block for them to add to a product data sheet.

Tg values were measured by dynamic mechanical analysis (DMA) to ASTM D7028 (1) and CTE by Thermal Mechanical Analysis (TMA) to ASTM ASTM 831 (2).

Tg measurements gave a mean value of 244.1°C.

CTE measurements gave mean values in X and Y of 2.39E-06 and 3.32E-06E-06m/m/°C.

These values are consistent with what would be expected for a material of this type.

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1 Introduction

CFP Composites Ltd have just launched a new tooling block material. This is a novel product being marketed as “360” made up of a nylon matrix reinforced with randomly orientated short carbon fibres. They are selling this product as a block material specifically into the composites tooling market. It allows for tools and patterns to be machined directly from this block to give a low CTE, high temperature capable tool. Compared to conventional laminated composite tooling this removes many of the process steps required. Compared to Invar metallic tooling, it is likely to offer a cheaper, shorter lead time tooling solution. CFP Composites Ltd approached The AMRC to see if we could measure some glass transition (Tg) and coefficient of thermal expansion (CTE) values for the 360 block for them to add to a product data sheet.

2 Method

2.1 Specimen Preparation

CFP Composites Ltd supplied a piece of the “360” carbon/nylon tooling material 300mm x 200mm x 20mm in size. This is shown in figure 1 with the X and Y orientations highlighted.

Samples were machined from this block using a CNC router to the dimensions shown in table 1 below. These were then hand polished on the edges with 240 grit abrasive paper and then dried in an oven for 1 hour at 60°C.

Figure 1. Showing the 360 carbon/nylon block material as received and the X and Y directions used.

Test specimen	Number of specimens	X (mm)	Y (mm)
X CTE	3	12	5
Y CTE	3	5	12
DMA	3	50	5

Table 1, Detailing specimen dimensions

2.2 Tg Measurements

The glass transition temperature (Tg) was measured using Dynamic Mechanical Analysis (DMA) to ASTM D7028 (1). For this test a small rectangular specimen is clamped between end supports with a probe clamped in the centre. This loads the specimen in three point bending as shown in figure 2 below. As the sample is heated up, the probe vibrates the specimen, effectively measuring its bending modulus. As the specimen approaches its Tg, the modulus starts to decrease allowing a Tg value to be calculated. Three specimens were tested on a Perkin Elmer DMA 8000 in dual cantilever mode. The temperature was ramped from 25-300°C, at 5°C/min and the loading frequency was 1Hz. Three specimens were measured, their dimension are shown in table 2 below. Note that for run 3 the sample was run initially up to 150°C, then cooled to Rt, then run up to 300°C, to see if this annealing process influenced the Tg at all, with no significant difference.

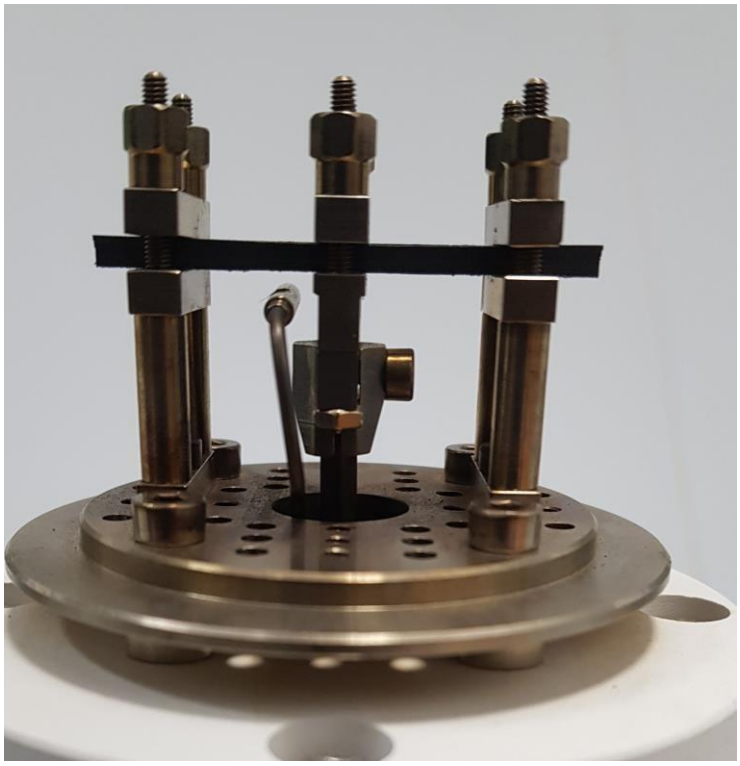

Figure 2. Sample shown supported for 3 point bending for Tg measurement by DMA

Specimen number	Length (mm)	Width (mm)	Thickness (mm)	Tg (°C)
1	12.35	5.29	2.96	243.18
2	12.15	5.27	2.85	246.56
3	12.33	5.02	2.23	242.72

Table 2. DMA specimen dimensions

2.3 CTE Measurements

The CTE was measured using Thermal Mechanical Analysis (TMA) to ASTM 831 (2). For this test a rectangular specimen is supported vertically in a quartz tube, with a quartz probe on the top surface. The quartz tube is lowered into a furnace, and as it is heated up the specimen expands. The displacement of the probe is measured and plotted against temperature from which the CTE can be calculated. The test set up is shown in figure 3 below. The samples were tested using a Perkin Elmer Diamond Thermomechanical Analyzer. The samples were heated from 30°C to 220°C at 10°C/min. The specimen dimensions were 12mm x 5mm x 6mm. Three specimens were tested in X and Y orientations, so 6 in total.

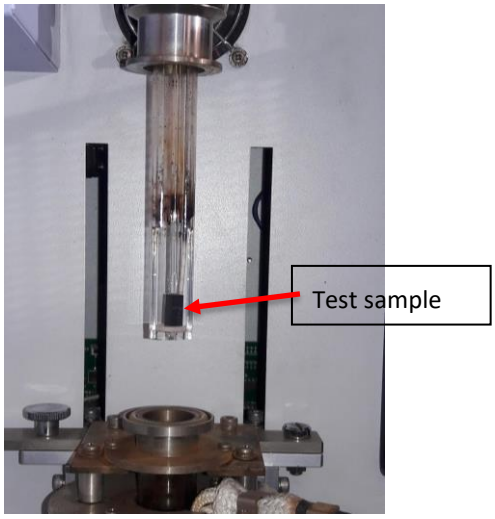

Figure 3. Showing the test sample in the TMA

3 Results and observations

3.1 Tg Results

The results from the Tg measurements by DMA are shown in table 3 below. The traces are shown in figure 4 below.

Specimen number	Tg (°C)
1	243.18
2	246.56
3	242.72
Mean	**244.15**

Table 3. Tg by DMA results.

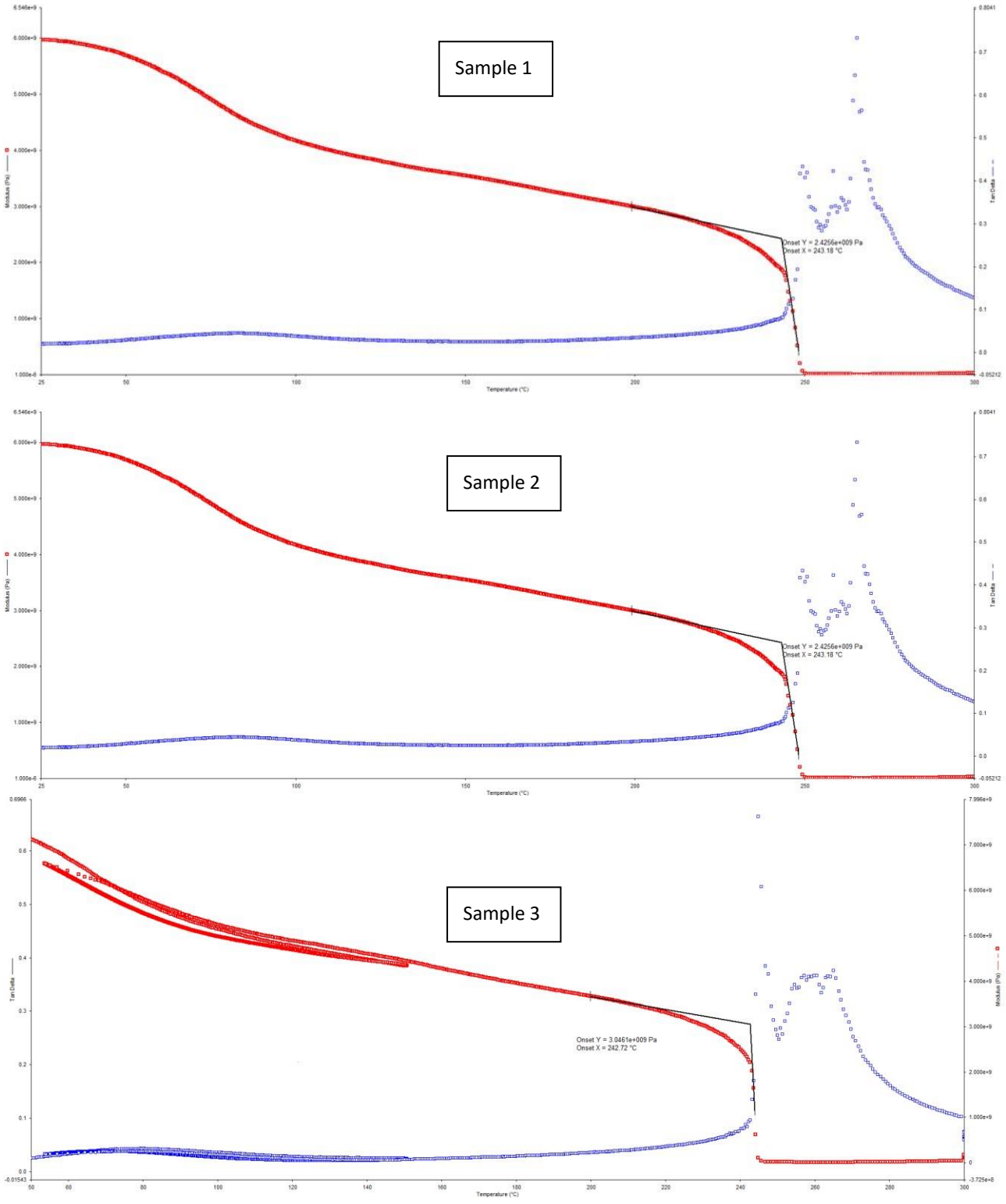

Figure 4. DMA traces

3.2 CTE Results

The CTE results are detailed in table 4 below. The individual traces for each direction are given in figures 5 and 6 below.

	Specimen number			
Test direction	1	2	3	Mean
X	2.17	2.46	2.55	**2.39**
Y	1.07	4.92	3.98	**3.32**

Table 4. CTE results. Note all values are times 10-06 m/m/^{o}C

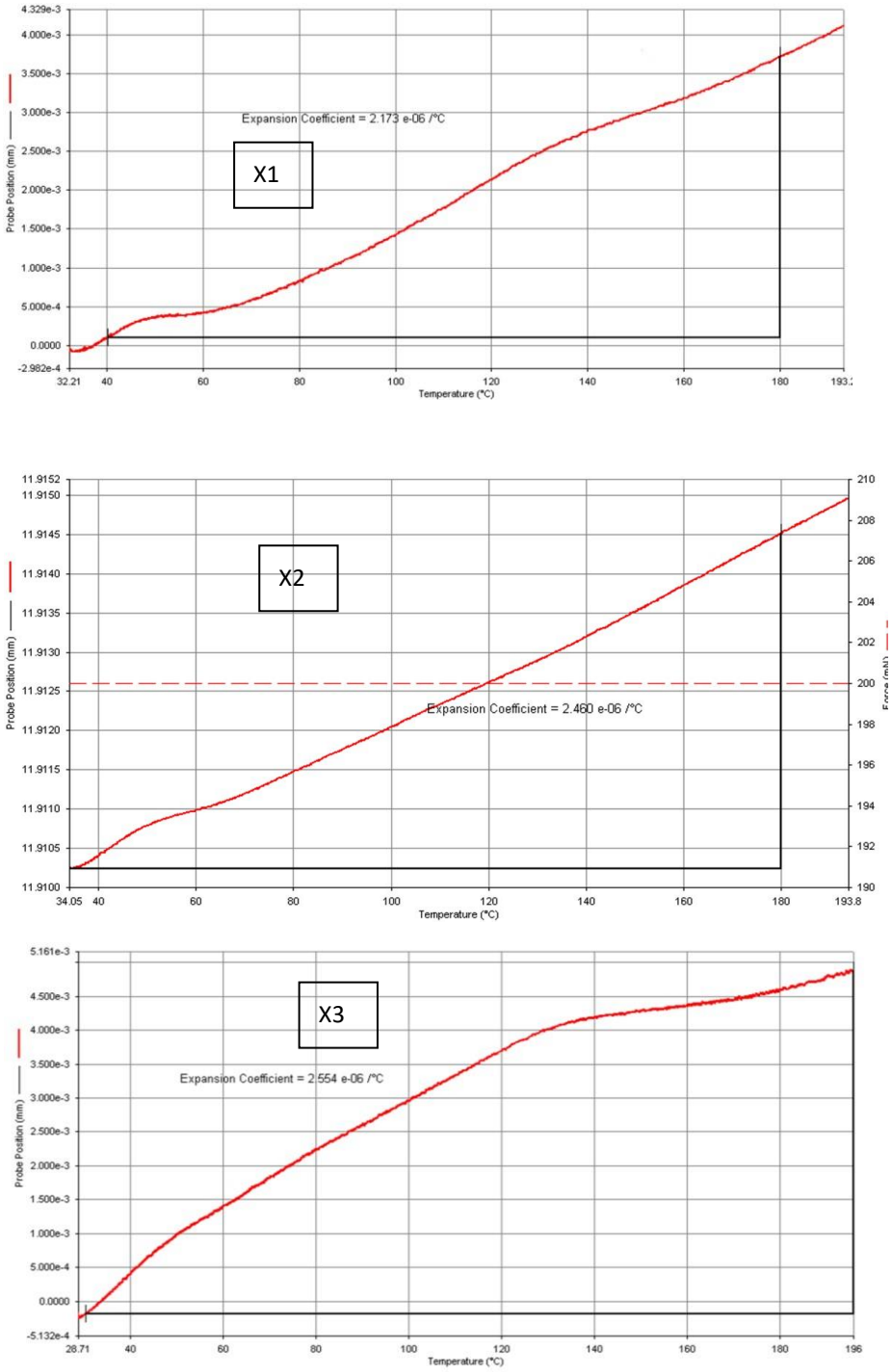

Figure 5. X direction CTE traces

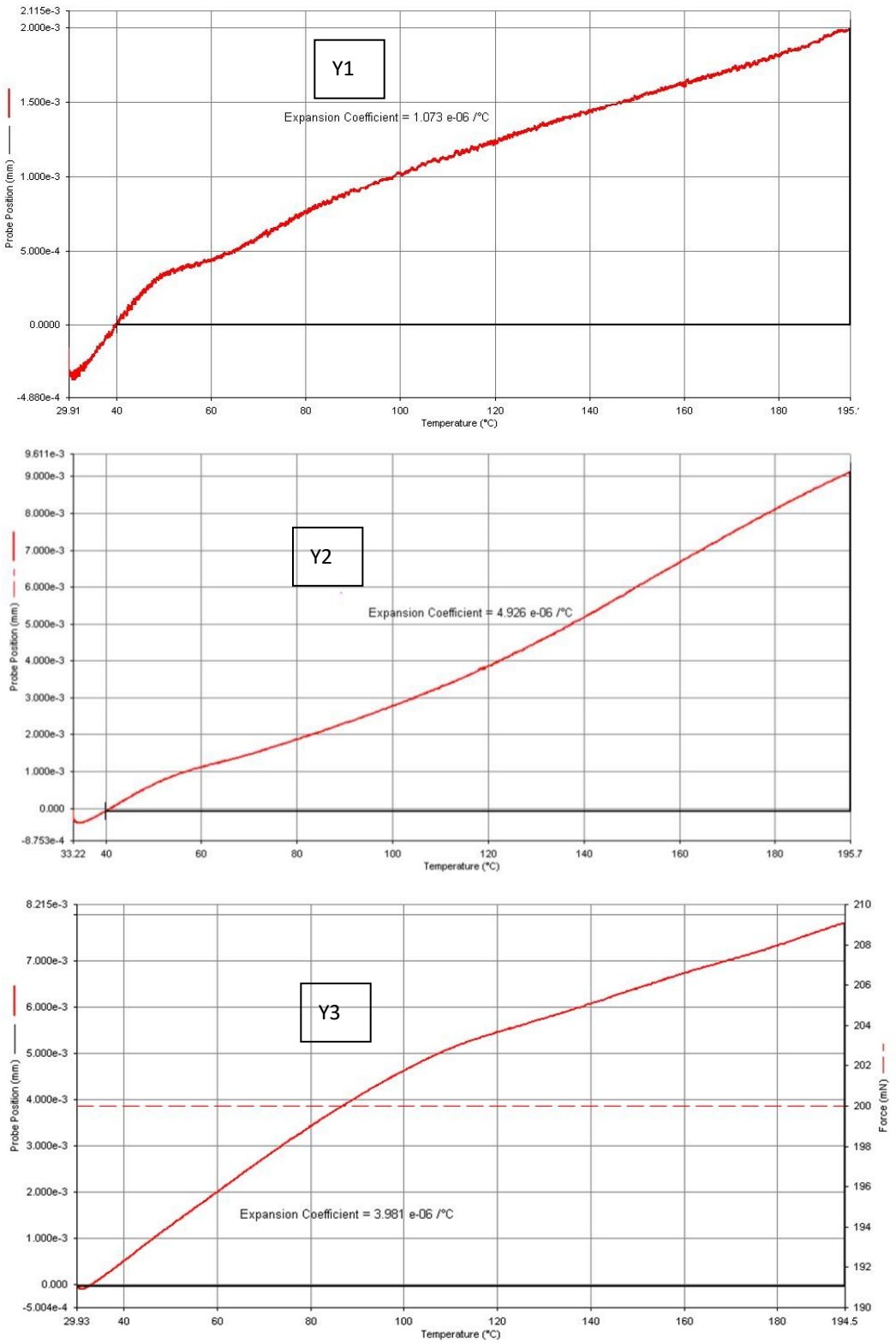

Figure 6. Y direction CTE traces

4 Conclusions

CFP Composites Ltd have asked The AMRC to measure Tg and CTE values for a novel carbon/nylon tooling block material they have developed.

Tg values were measured by dynamic mechanical analysis (DMA) to ASTM D7028 (1) and CTE by Thermal Mechanical Analysis (TMA) to ASTM ASTM 831 (2).

Tg measurements gave a mean value of 244.1°C.

CTE measurements gave mean values in X and Y of 2.390E-06, 3.32E-06m/m/°C.

These values are consistent with what would be expected for a material of this type.

5 References

1. ***ASTM D7028 - 07(2015) Standard Test Method for Glass Transition Temperature (DMA Tg) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA).***
2. ***ASTM E228-17 Standard Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer.***