# AXIAL FATIGUE BEHAVIOUR OF GLASS FIBER REINFORCED ARNITE® PET

**Performed by:**
Amine MOUBARIK
PhD, Chemistry and Physical-chemistry of polymers

**Approved by:**

Valerie NASSIET and Sebastien MISTOU

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## I. SCOPE

The main aim of this investigation was to study the stress-controlled tensile fatigue of a glass fiber reinforced Arnite® PET.

## II. SAMPLES DESCRIPTION

The Arnite® PET (Figure 1) materials have been bought from DSM Engineering Plastics.

**Figure 1.** Arnite® PET

Samples tested by ENIT have been processed by Pau University and Minho University to compare by tensile test the process influence on mechanical properties, according to the following conditions (Table 1):

**Table 1.** Injection molding parameters for GF35_Pau, GF0_Pau and GF0_1C15A_Pau

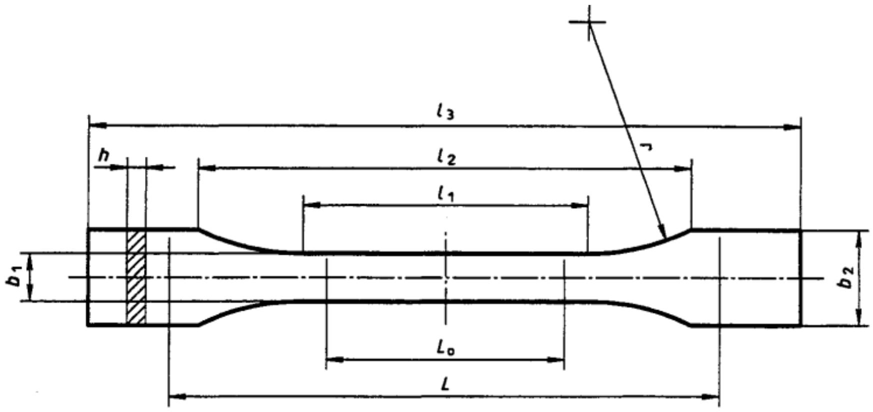
| | **GF0_Pau** | **GF35_Pau** | **GF0_1C15A_Pau** | **GF35_Minho** |
|---|---|---|---|---|
| Injection rate (mm/s) | 60 | 85 | 25 | 30 |
| Barrel temperature (°C) | 290-290-290-285 | 300-300-290-280 | 290-290-290-285 | 270-275-280-280-290 |
| Holding pressure (bar) | 70 | 10 | 30 | 20 |
| Holding time (s) | 11 | 5 | 11 | 5 |
| Cooling time (s) | 30 | 30 | 25 | 10 |
| Mould temperature (°C) | 45 | 80 | 45 | 130 |
| Back pressure (bar) | 5 | 25 | 5 | 5 |
| Speed screw (rpm) | 130 | 130 | 130 | 100 |
| Injection pressure (bar) | 125 | 65 | 90 | 40 |

## III. TEST CONDITIONS

### III.1 Tensile test

Tensile test were obtained according to standard ISO 527-2. Test specimen dimensions are exposed in

Figure .




| L | Lo | l1 | l2 | l3 | b2 | b1 | h | r |
|---|---|---|---|---|---|---|---|---|
| 115 ± 1 | 50.0 ± 0.5 | 80.0 ± 2 | 104 - 113 | 150 | 20.0 ± 0.2 | 10.0 ± 0.2 | 4.0 ± 0.2 | 20 - 25 |

**Figure 2:** Specimen test dimensions according to standard ISO 527-2 (mm)

The tensile test conditions are:

***Speed test:*** 2 mm/min

***Preload:*** 3 N

***Test temperature:*** Ambient (20 ± 1ºC)

***Load Cell:*** 50KN

***Test equipment:*** INSTRON 33R4204
Mechanical extensometer

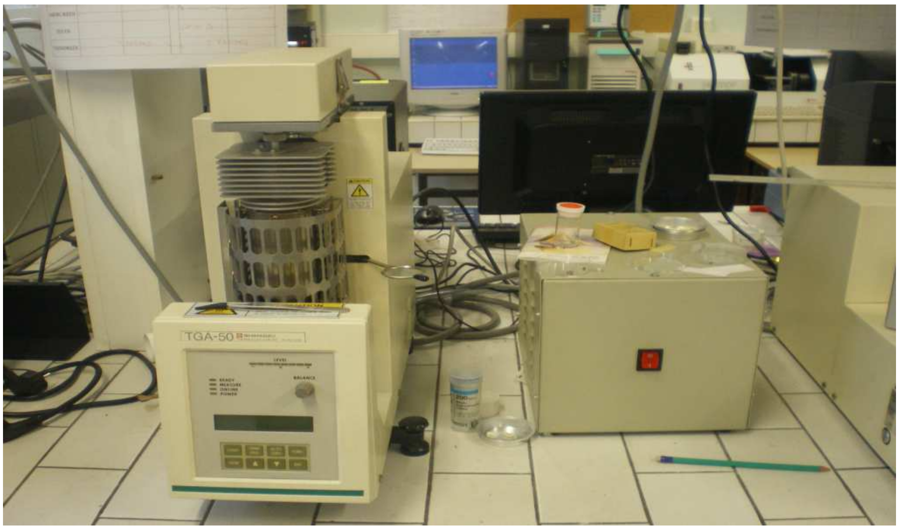
III.2 Fatigue test

The fatigue tests were performed using a SCHENCK 8800 (INSTRON) on samples processed at Pau University. The tests were conducted at stress ratio, $R = \frac{\sigma_{min}}{\sigma_{max}}$=0.1 with a sinusoidal waveform at a frequency of 20 Hz. The tests were carried out at several different maximum stress levels, starting with 85%, 70%, 50% and 30% of the tensile strength at break. All the tests were carried out at a temperature of 20°C.

III.3 TGA analysis

The tensile test conditions are:

| | |
|---|---|
| ***Test equipment:*** | TGA - 50 |
| ***Test atmosphere:*** | oxygen |
| ***Test temperature:*** | Heat from 22°C to 850 °C at 5 °C/min |




**IV. TEST RESULTS**

IV.1 Tensile test

Figure 3 shows the stress-strain curves obtained during the tensile tests of GF0_Pau, GF35_Pau, GF35_Minho and GF0_1C15A_Pau. The results are summarized in Table 2. The elastic modulus and tensile strength were calculated from the slope of initial linear segment and the maximum stress in the stress-strain diagram, respectively.

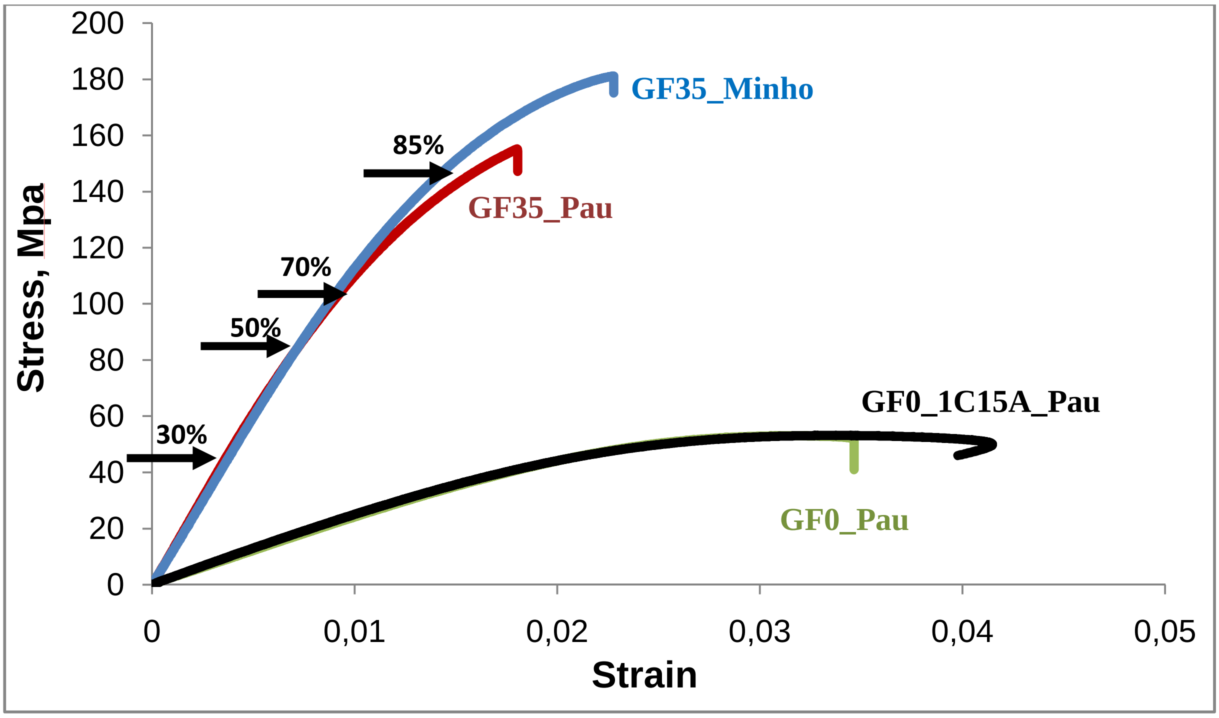



**Figure 3.** Stress-strain diagram of test materials

**Table 2.** Tensile properties of GF0_Pau and GF35_Pau

| Material | Tensile strength, MPa | Tensile modulus, MPa |
|---|---|---|
| **GF0_Pau** | 53 ± 1.34 | 2395 ± 54 |
| **GF35_Pau** | 160 ± 4.38 | 12474 ± 195 |
| **GF35-Minho** | 179 ± 2.5 | 12594 ± 616 |
| **GF0_1C15A_Pau** | 53 ± 0.78 | 2685 ± 138 |

The tensile strength determined from these tests were then used as the fatigue test parameters.

## IV.2 Fatigue test

The fatigue test results obtained for the GF35_Pau are shown in Figure 4. A horizontal arrow on a data point indicated that the specimen did not fail at 10 million of cycles. The experimental data of stress vs. number of cycles to failure for the GF35_Pau shown in Figure 4 was fitted well by the following equation:

$$\sigma_{max} = 220.02e^{-0.228LogN}$$

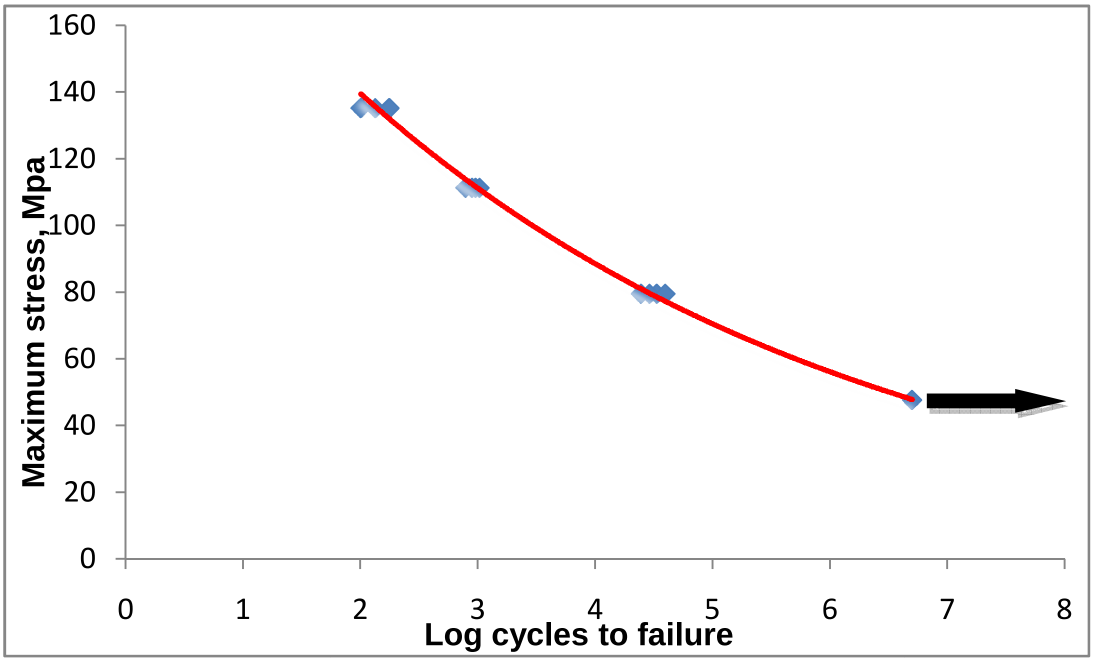



**Figure 4.** The logarithmic stress-life curve for GF35_Pau composite.

**Figure 5** shows the mean temperature rise vs. cycles to failure for the GF35_Pau composites tested at $\sigma_{max}$= 85%, 70% and 50% of tensile strength. Temperature has been evaluated by Infra-red thermography (CEDIP JADE MWIR). We note that the temperature increased during the fatigue test, with ΔT between 10°C for $\sigma_{max}$= 85% and 25°C for $\sigma_{max}$= 50%.

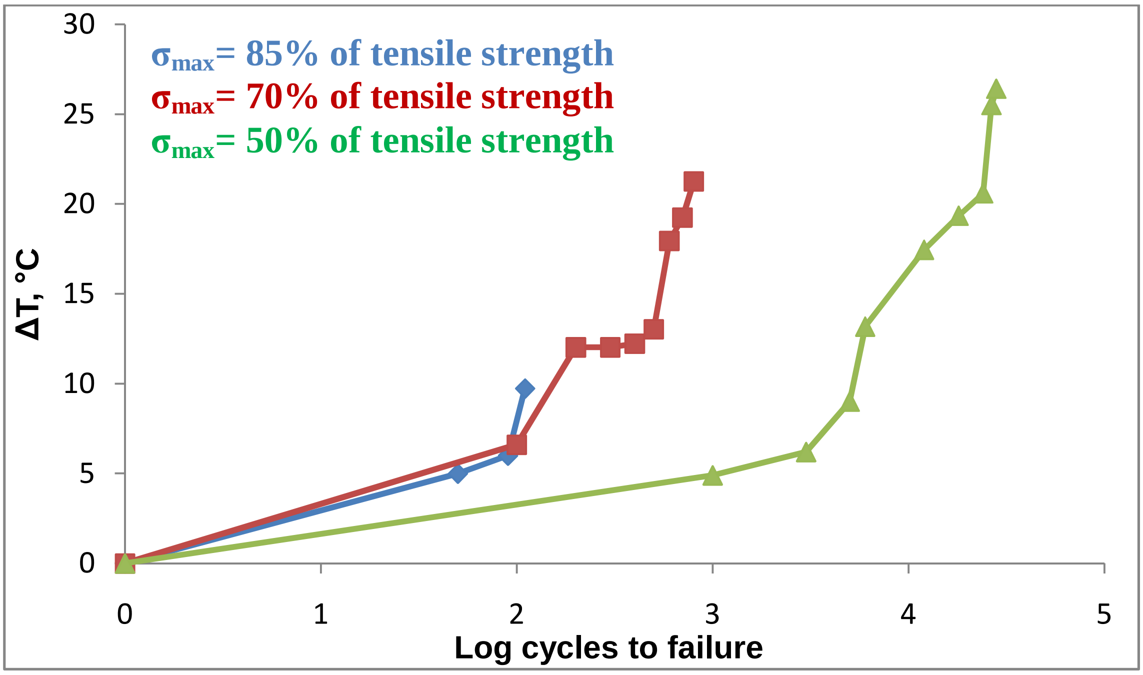



**Figure 5.** Temperature rise during fatigue testing in GF35_Pau specimens. R= 0.1 and frequency 20 Hz.

Figure 6 shows the temperature evolution measured at surface positions (see Figure 7) along the specimen length and Figure 7 an example of the 2D spatial temperature distribution on specimen surface. The temperature at the specimen surface is found to be homogeneous along the specimen axis until close to $T_g$. around 60°C precisely rupture localization starts close to the grip equipment.

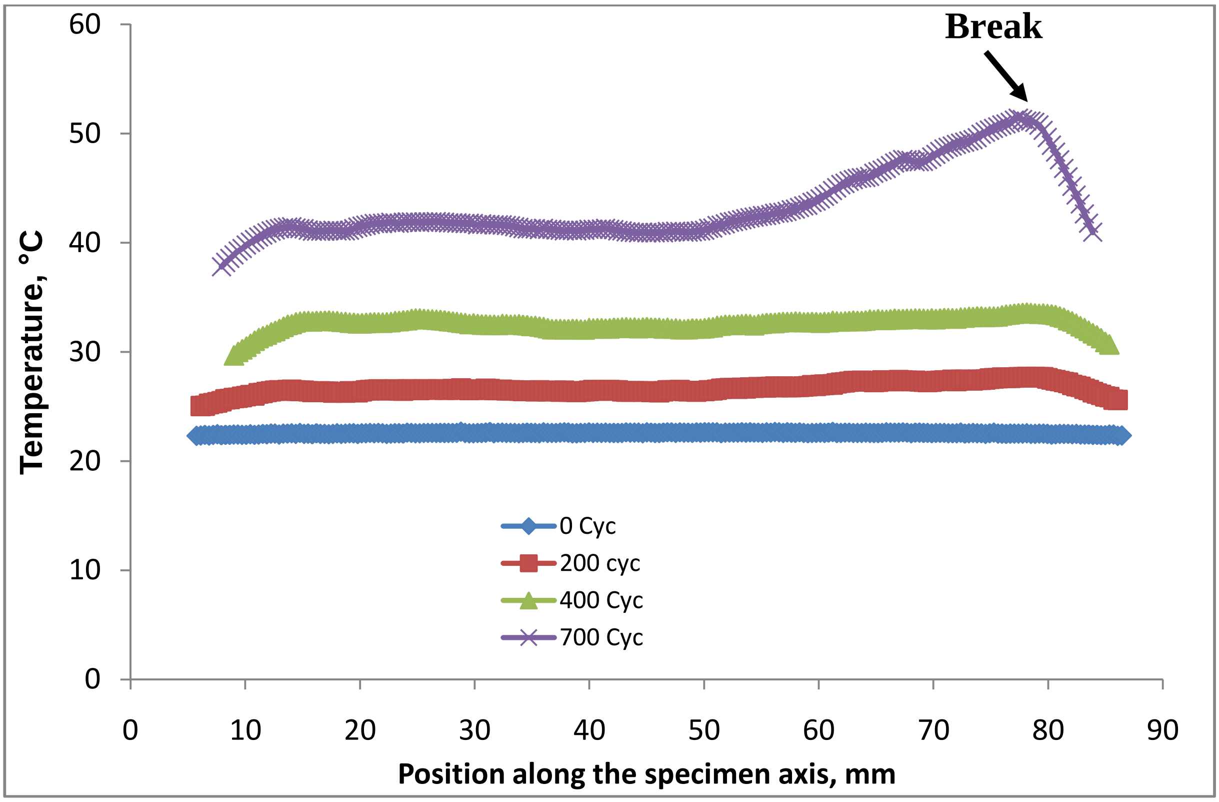



**Figure 6.** Temperature distribution along the specimen axis at different fatigue stage for GF35_Pau. R= 0.1, frequency 20 Hz and $\sigma_{max}$= 70% of tensile strength.

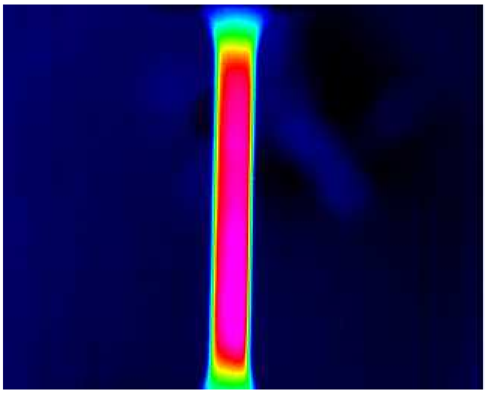


**Figure 7.** 2D spatial temperature distribution on specimen surface at 700 cycles for GF35_Pau. R= 0.1, frequency 20 Hz and $\sigma_{max}$= 70% of tensile strength.

IV.3 TGA analysis

Figure 8 shows the TGA analysis of GF35_Pau, GF35_Pau after fatigue test at $\sigma_{max}$ = 85%, 70% and 50% in air atmosphere at a heating rate of 5 °C/min.

The decomposition of GF35_Pau consisted of two steps (combustion and pyropysis) at 390 and 470 °C correspond respectively to the GF35_Pau decomposition and char decomposition. In the first step considerable part of the initial material decomposes between 390 – 450 °C. When this first decomposition of the main part of the material is finished, there is a second step, which leads to the total consumption of the remaining char. The fatigue test does not significantly alter the beginning of the thermal decomposition. On the other hand, the fatigue test influences the second step.

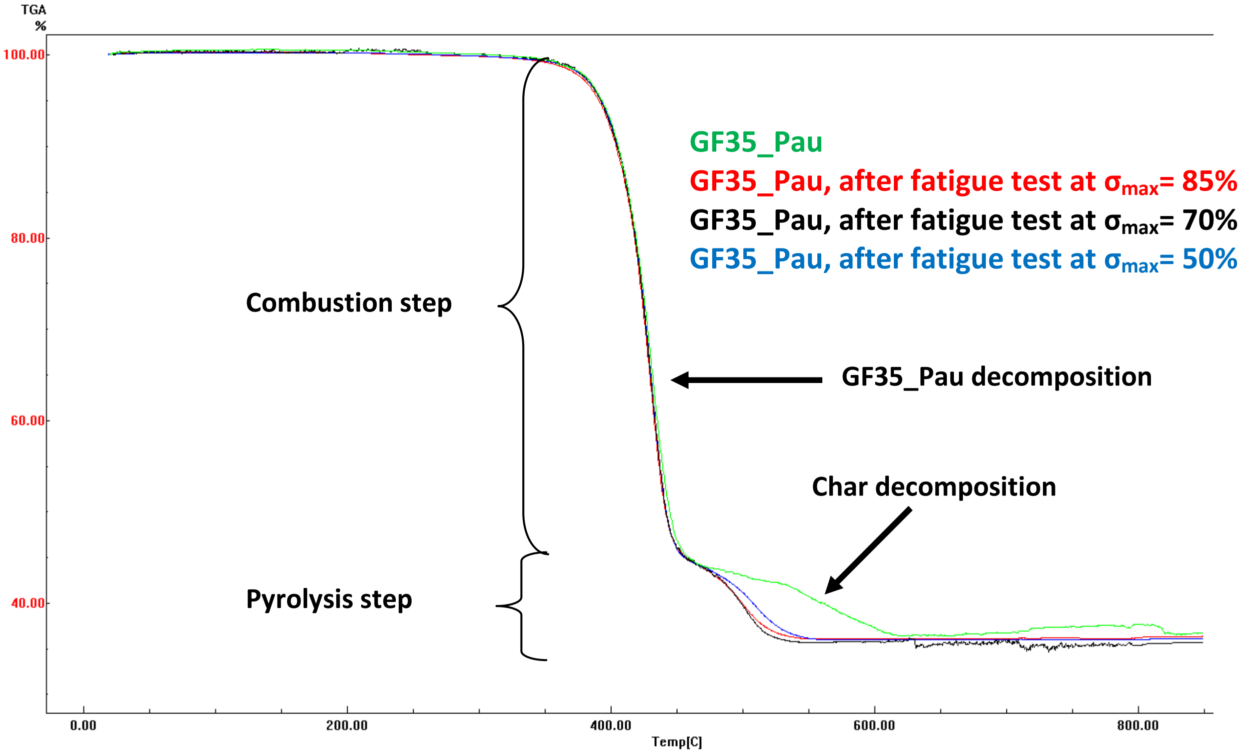



**Figure 8.** Comparison of TGA analysis of GF35_Pau, GF35_Pau after fatigue test at $\sigma_{max}$ = 85%, 70% and 50%.

## V. CONCLUSION

Based on the experimental results obtained, the following conclusions can be made:

- Addition of glass fiber improved the mechanical properties (Tensile strength and tensile modulus); The results of the tensile test of the materials processed under Pau and Minho conditions are according to the specifications given in the material data sheet
- The S – N curve for GF35_Pau showed that as the maximum stress was exponentially reduced with number of cycles to failure increases, allowing to define a predictive law. However, the endurance limit has not been reached
- Under axial fatigue, GP35_Pau fail by thermal softening when the local surface temperature is close to their glass transition temperature.