Study of the optimal, thermal, morphological and mechanical characteristics of a laser weldable fibre reinforced polymer

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Introduction

The automotive, electronics and medical industries have expanded the use of equipment made with reinforced Polybutilene Tereftalate (PBT), allowing for more complex designs, high rigidity and low cost [1-3]. This work shows a characterization process of PBT reinforced with 30% of glass fibres in weight, supplied by BASF as a laser-weldable fiber reinforced polymer.

Experimental methodology

To characterize weld bead material during a laser welding process, samples were submitted to controlled heat treatments in a closed oven at two temperature (237ºC and 257ºC) beyond melting temperature (225ºC) (Fig. 1a). To determine the absorbance and transmittance of the material, it was characterized via (FTIR) and the Beer-Lambert law (Fig 1b) was calculated.

Morphological properties were first determined from a visual analysis (Fig. 2a) showing diffuse reflection from degradation and micrographs illustrating the growth of defects with remelting temperature (Fig. 2b).

Experimental results

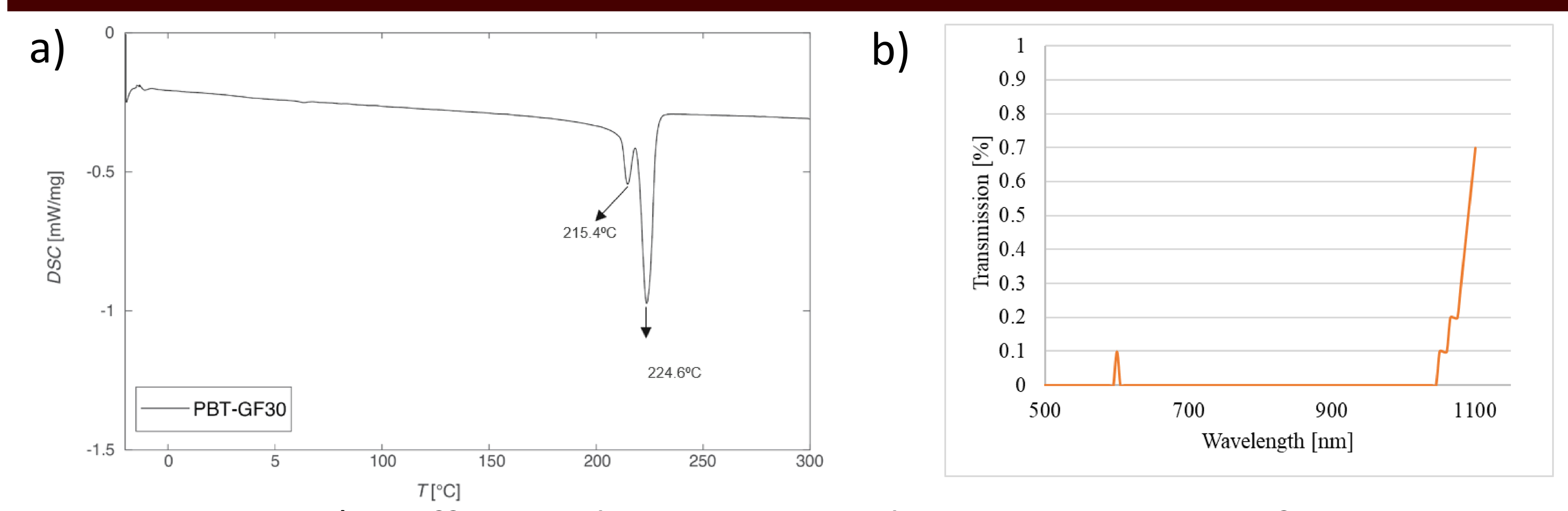

Figure 1 – a) Differential scanning calorimetry curve of PBT GF30. b) Representative FTIR transmittance curve of PBT GF 30 in the as received state.

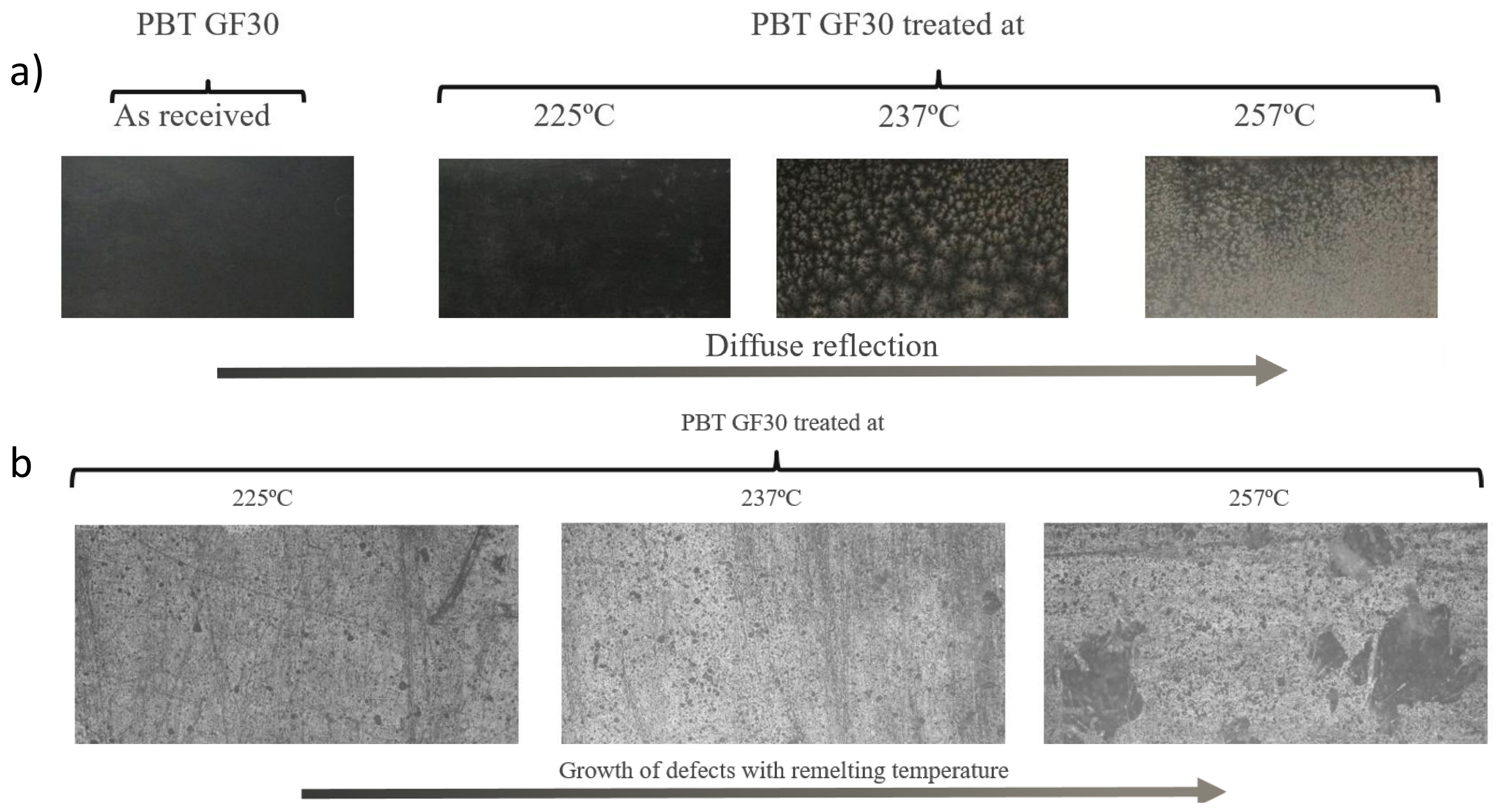

Figure 2 – a) Representation of the sample surfaces of PBT GF 30, illustrating the evolution of the material when submitted visual light with the increasing higher temperatures. b) Degradation surface showing the defects with increasing higher remelting temperature.

The hardness (figs. 2a), stress intensity factor (fig. 2b) and mechanical resistance (fig. 3c) of the PBT GF 30 as received and treated following relevant standard [4-6].

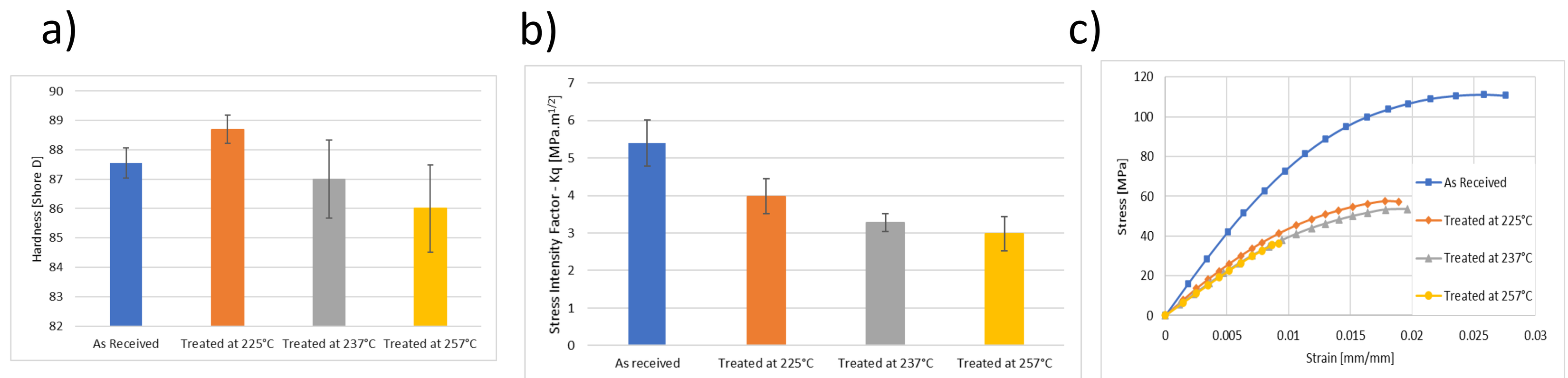

Figure 3 – a) Hardness, b) Resistance and c) Stress intensity factor of PBT components.

Numerical procedure

Two different numerical models were created in this work, simulating both the tensile test (Fig. 4a) using elastoplastic and ductile damage in 3D and the compact tension tests (Fig. 4b), employing max plane stress damage coupling XFEM in 2D. The model properties are shown in Table 1.

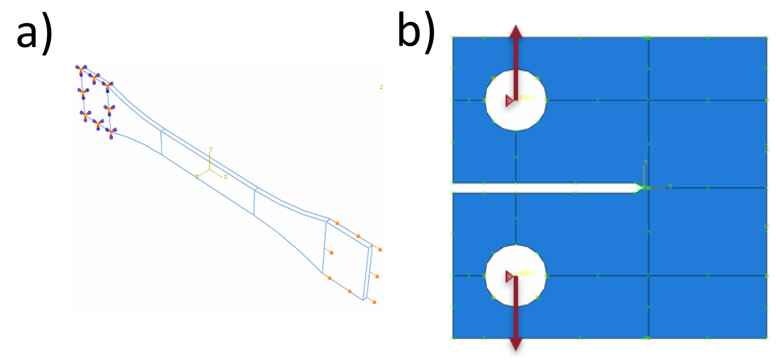

Figure 4 – Boundary condition. a) Tensile test condition in 3D. b) Compact test condition in 2D.

Table 1 – Properties and parameters of the model.

	Material - PBT GF 30			
	As received	Treated at 225°C	Treated at 237°C	Treated at 257°C
Max principal stress (MPa)	67	40	39	37.7
Displacement at failure	0.33	0.33	0.33	0.12
XFEM - crack size (mm)	1	1	1	1

Numerical results

Fig. 5a and Fig. 5b show the comparison between experimental and numerical response of the tensile test. Fig. 5c shows the representative model comparing the experimental and numerical fracture.

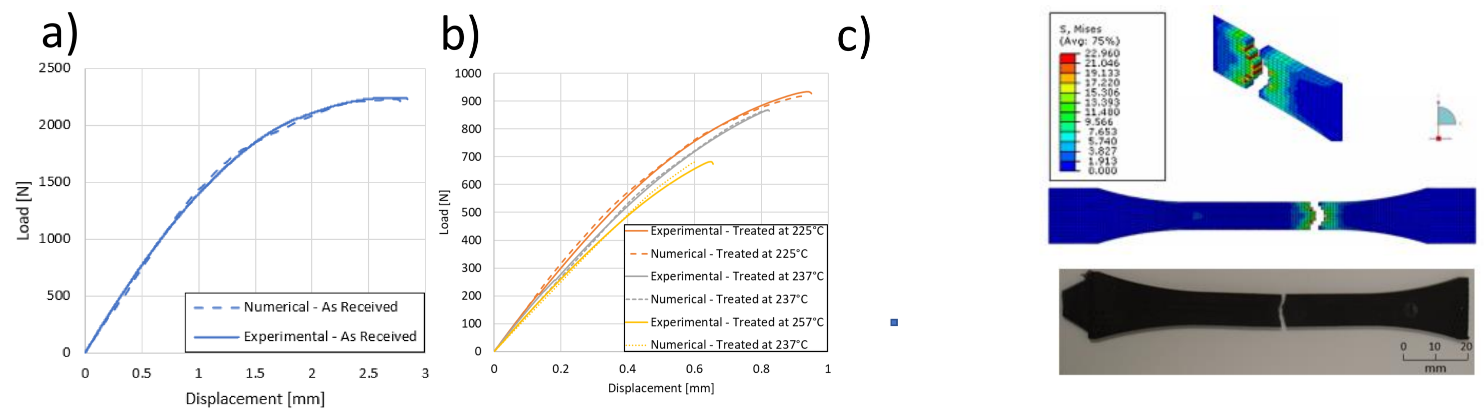

Figure 5 – a) Representative tensile test curves of the PBT GF 30 as received. b) Tensile test curves of the PBT GF 30 treated.

Fig. 6a and Fig. 6b show the comparison between experimental and numerical to PBT components to compact tension test. Fig. 6c shows the representative model comparing the experimental and numerical fracture.

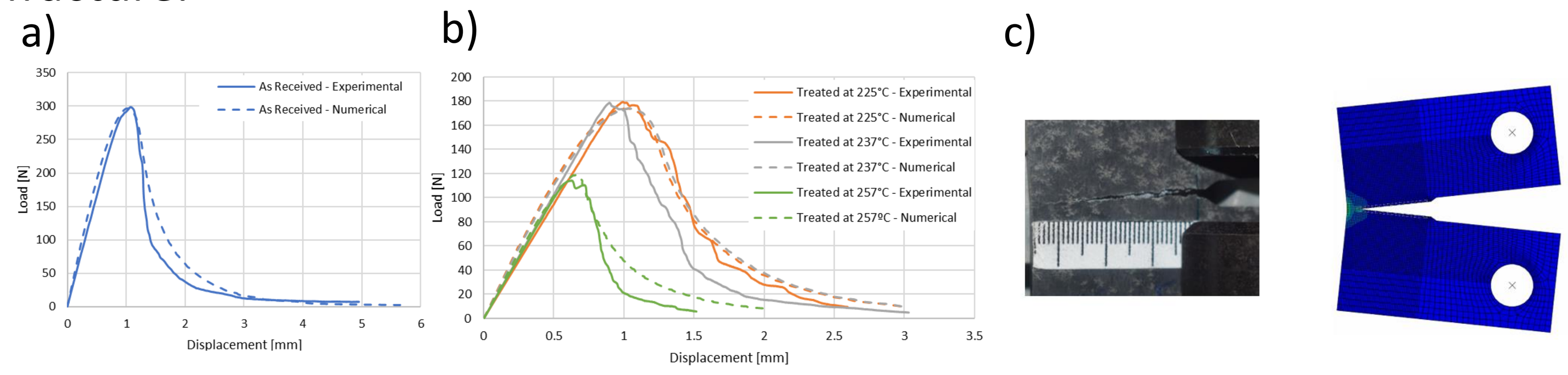

Figure 6 – a) Representative load-displacement curves PBT GF 30 as received. b) Load-displacement PBT GF 30 treated.

Conclusions

In this work, a detailed characterization of the thermal, optical, mechanical, and morphological characteristics of PBT-GF30 was carried out.

- The influence of thermal energy on the behaviour of the material allowed to characterize the response of the material to the thermal conditions encountered during laser welding operations.
- The thermal and mechanical analysis shows that even if the conductivity coefficient is low, the incident laser energy can still lead to a drop in the mechanical properties in the weld bead and its surroundings.
- Finally, numerical models were created to validate the experimentally determined mechanical properties. A ductile damage behaviour was found to be able to reproduce the tensile test, while the compact test employed max plane stress damage (Maxps) implemented in XFEM.

References

[1] Bendrea, A.-D., L. Cianga, and I. Cianga, Progress in the field of conducting polymers for tissue engineering applications. Journal of biomaterials applications, 2011. 26(1): p. 3-84.

[2] Unterweger, C., O. Brüggemann, and C. Fürst, Synthetic fibers and thermoplastic short-fiber-reinforced polymers: Properties and characterization. Polymer Composites, 2014. 35(2): p. 227-236.

[3] Diebels, S. and S. Rjasanow, Multi-scale simulation of composite materials: Results from the project MuSiKo. 2019: Springer.

[4] ASTM, C., *ASTM standards.* Philadelphia: American Society for Testing Materials, 1958.

[5] ISO, B., Plastics–determination of tensile properties. 1997.

[6] ASTM, I., Standard test methods for plane-strain fracture toughness and strain energy release rate of plastic materials. ASTM D5045-99, 2007

Acknowledgements

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