Electro-thermal analysis of CB/PLA produced by additive manufacturing

ELECTRO-THERMAL ANALYSIS OF CB/PLA PRODUCED BY ADDITIVE MANUFACTURING

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Introduction

4D-printing is defined by the use of 3D-printing combined with a smart material reacting to an external stimulus, the fourth dimension referring to time [1-2]. Thermally activated Shape Memory Polymers (SMP) are used due to their ability to change their shape to a pre-programmed one if their temperature rises above their glass transition temperature [3]. Such components can be 3D-printed by Fused Deposition Modeling (FDM). In particular, black carbon reinforced polymers that are able to conduct electricity and to heat thanks to the Joule effect are of great interest for 4Dprinting [4]. Actuators with applications in aerospace, drones or even robotics can be imagined. In this work, the determination of the thermal and mechanical characteristics and results on electrothermal experiments on such composite are presented.

Materials and methods

The filament used is a carbon/polylactic acid (CB/PLA) composite from Proto-Pasta. CB/PLA is 3D-printed in an Ultimaker 2 Extended + printer with a nozzle diameter of 0.8mm. Thermal characterisation is conducted by means of a Differential Scanning Calorimetry (DSC) Q20 from TA Instruments. Tensile tests are performed on the raw filament using an INSTRON 5982 machine with a cross-head speed of 0.5mm/min. Marker tracking with a gauge length of 40mm is used for the measurement of longitudinal strain. For studying the Joule effect, rectangular specimens with a dimension of 70x20x1 mm^3 are 3D-printed with a 0° raster angle. A DC power supply AL936N is used to apply a voltage up to 35V to heat the samples. Temperature is measured both by a K-type thermocouple with a diameter of 0.25mm and an infra-red Infratech Variocam HD Head 680 camera.

Results

Results show that the raw filament is amorphous and have a Young's modulus of 3 GPa (Fig.1). A specific procedure has been developed to optimise the electrical contact between the composite specimen and the electric circuit (Fig.2). Thanks to this procedure, the 3D-printed specimen resistance is reproducible and has been measured equal to 182ohm. The evolution of the Joule heating kinetics and the maximum temperature reached as a function of the applied current voltage is quantified. Moreover, microscopic observations of the samples are performed in order to better understand the Joule effect phenomenon in these materials.

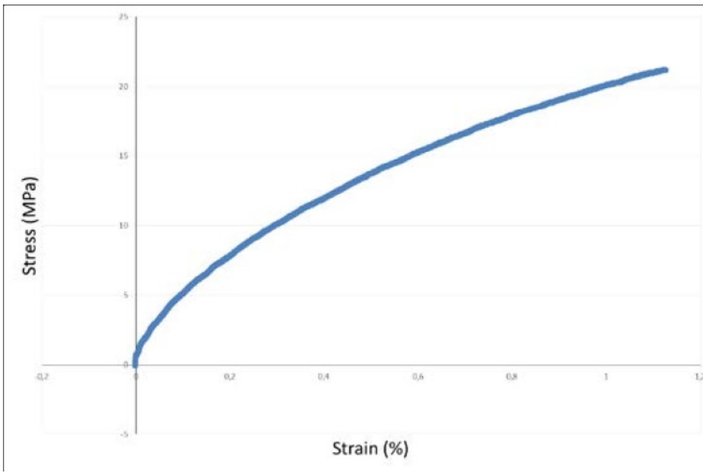

Fig.1 – Tensile curve of a filament of CB/PLA

Fig.2 – Experimental setup for the resistance measurement

Conclusions

CB/PLA is a good candidate for electrically activated 4D-printing. The samples used can be heated above the glass transition temperature of the material with a reasonable voltage and the maximum temperature is reached in less than four minutes. Future work will involve the study of the replicability of Joule heating of the samples and their answer to a repeated stimulation.

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