

CARBON TOW FILAMENTS AND THEIR COMPOSITES AS STRAIN SENSORS



AUTHORS

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Introduction

- Structural Health Monitoring of the building structure, sensing low strains by measuring the electrical resistance of the strengthening composite material.
- Use of Carbon Filaments Epoxy Composites for both strengthening and monitoring of the structure.
- Self-sensing technique based on the change of the electrical resistance of the composite caused by deformation and damage.
- The strain monitoring by electrical resistance measurement has been based in two types of measurement: the through-thickness conductivity and the longitudinal conductivity (along the filament direction) measurement.

EXPERIMENTAL METHODS

Materials and specimens

Carbon tow

- PAN-based carbon filaments from the company SGL group
- The filaments are embedded in the epoxy-resin S&P Resin 55

Table 1. Carbon continuous filament tow properties.

SIGRAFIL C type	Number filaments	Fineness of tow [tex]	Tensile strength [GPa]	Tensile modulus [GPa]	Elongation at break [%]	Filament diameter [μm]	Density [g/m^3]	Single filament resistivity [$\mu\Omega$]
C ₃₀ TO ₅₀ EPY (Enhanced modulus)	50k	3200	4.0	253	1.6	7	1.80	15

Carbon composite specimens to test at the dynamometer

- The following table shows the general characteristics of the specimens made to test in the dynamometer.

Table 2. Dynamometer specimens

Carbon filament tow without resin	
with 50k number of filaments (3 performed tests in the same sample)	
Carbon filament tow in epoxy-resin with 3 days	
<50k	<50k with eight cuts
<50k/<50k	<50k long
50k with six cuts	
Carbon filament tow in epoxy-resin with 7 days	
50k/50k	<50k/50k
<50k with 8 cuts	1 Transversal/1 longitudinal

EXPERIMENTAL METHODS

Performed tests

Tensile-strain tests while recording the electrical resistance

- Specimens were tested in the dynamometer (Adamel Lhomargy DY35) and at the same time the electrical resistance was recorded.
- Electric resistance recorded with a multimeter (Keithley 197A) connected to the extremities of the probe.

Table 2. Dynamometer tests characteristics.

Initial Length	500mm
Velocity of test	1mm/min

Tensile-strain tests while recording the electrical resistance

Figure 1. (a) Example of probe in the dynamometer. (b) Emphasis on the connections to measure the electrical resistance.



(a)



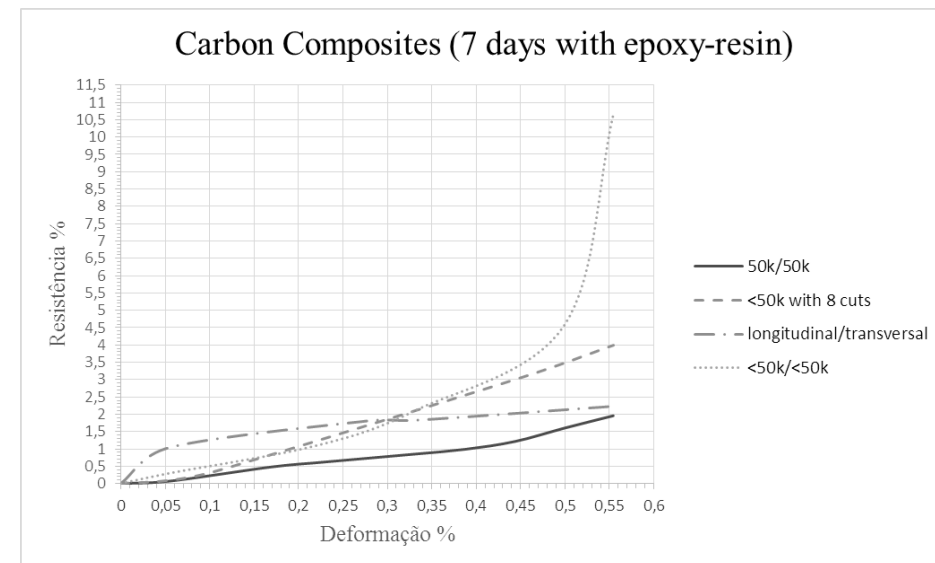
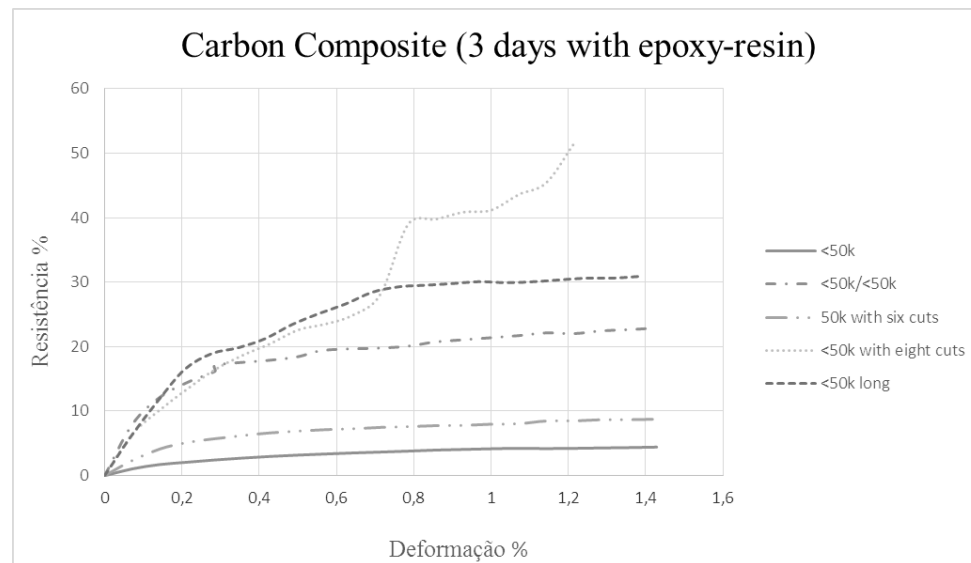
(b)

RESULTS

And discussions

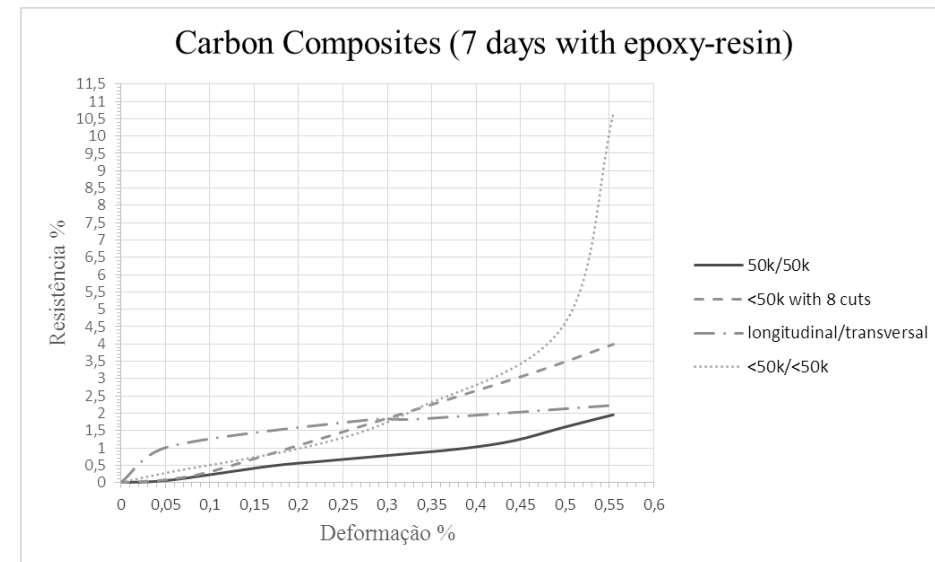
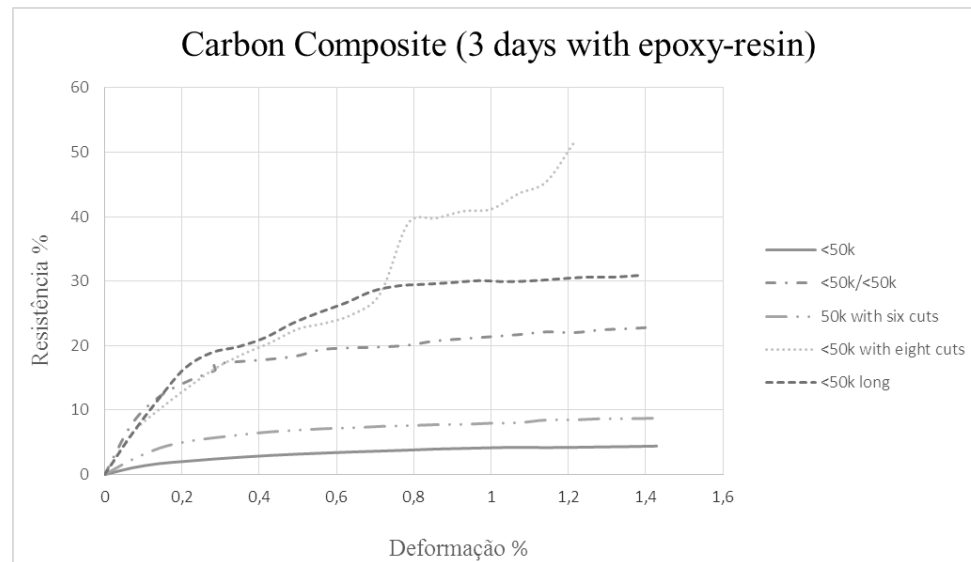
- For all tested specimens the small strains cause an increase in the electrical resistance. The initial resistance of these 500 mm long tows was deliberately diverse, varying from 9 Ω (for the thick tow with eight cuts) to 350 Ω (for the thin tow with long length - snake design).
- Despite this large range of magnitude of the electrical resistance, in all specimens the fractional change of the electrical resistance was sensing the deformation. But, as expected, higher electrical resistances enhance this sensing ability.

Figure 2. Fractional increase in electrical resistance ($\Delta R/R_0$), in percentage, as function of the strain.



- The increase of electrical resistance caused by an increase in strain may occur because the filaments, that are covered with the epoxy-resin, become more aligned and thus the contact points between filaments decrease.
- The introduction of deliberate disruptions on the conductive pathway, by random cuts, (<50k with 8 cuts) enhanced the sensing ability. Similarly, the sensing of strain by measuring the contact electrical resistance (<50k/>50k) shows a very good performance.

Figure 2. Fractional increase in electrical resistance ($\Delta R/R_0$), in percentage, as function of the strain.



- The importance of the reinforce of the concrete for that the thicker the carbon filaments the better we can provide the necessary performance of the building structures,
- In this case the same reinforce material can become a strain sensor to detect small deformation on the concrete and reinforce building structures.

Conclusions

For all tested specimens, the electrical resistance of the carbon filaments epoxy composites change with low strains, increasing with an increase of strain.

Carbon filaments and their composites may have the ability to become strain sensors for monitoring buildings, roads, bridges...

The usual carbon strengthening materials may act as self-sensing technique for the health monitoring of buildings. This way sensors are part of a multi-function material that is light weight and low cost.

By introducing some specific and simple designs on the geometry of the filaments that integrate the strengthening textile fabric, the self-sensing ability of the fabric might be improved.

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THANKS

FOR YOUR ATTENTION