Data Article

Experimental data on electrical properties of epoxy/carbon composites used as structural capacitance

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Article info
Article history:
Received 4 October 2019
Accepted 15 November 2019
Available online 22 November 2019

Keywords:
Woven composites
Carbon fibres
Structural capacitance
Multifunctional composites
Electromechanical composites

Abstract
This data article reports experimentally measured electrical properties of a plain-woven epoxy/carbon fabric composite used as structural capacitance. The composite laminate was fabricated via the hand lay-up technique with a polyethylene (PET) film sandwiched between the layers. The composite layers acted as electrodes while the PET film acted as the dielectric separator. The electrical properties of this composite laminate capacitor were measured by connecting it to an automatic LCR meter via copper connectors. The properties measured included the series and parallel resistance, series and parallel capacitance and the capacitance density. The data allows assessment of the electrical performance of this composite when fabricated via the hand lay-up method. The data can be used for comparison with similar or other composites, employing the same or more sophisticated fabrication techniques, and for assessing the composite’s multifunctional capabilities.

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https://doi.org/10.1016/j.dib.2019.104867
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1. Data

The data presented here include the electrical properties of the epoxy/carbon fabric plain woven composite laminate specimens, intended to be used as structural capacitance and fabricated by the hand layup technique. Hand lay-up is the simplest and most economical composites moulding method and also the crudest. As such the electrical properties of specimens thus prepared can be considered to be a lower bound, with improvements expected with increasing sophistication of the fabrication process. The specimens consist of 4 layers with one PET film sandwiched between the second and third layer. Each pair of the carbon fabric layers acts as an electrode while the PET film acts as the dielectric separator. The electrical properties considered are series and parallel resistance, series and parallel capacitance and the capacitance density.

2. Experimental design, materials, and methods

The composites were fabricated by using 3K plain woven carbon fabric purchased from Fiber Glast Inc (3k indicates 3000 filaments per fibre). The resin used was the system 2000 epoxy resin and the curing agent was the 2120 two-hour epoxy cure, both purchased from Fiber Glast Inc as well. A Polyethylene terephthalate (PET) film was used as the dielectric separator and was 0.05 mm or 50 μm thick (trade name: DuPont Mylar A).

The epoxy resin was mixed with the hardener in a ratio of 100:27 by weight as specified by the supplier. Then the carbon fabric layers were placed by hand one by one on a flat panel lined with the peel ply. The carbon fabric layers were approximately 200 mm × 450 mm in size. The resin/hardener mixture was applied onto each layer with the aid of a brush. Between the second and third layer, a PET
film was added. The PET film was placed so that it was fully contained within the carbon fabric layers. The stack of these layers was then vacuum bagged, sealed and connected to a General Electric 1/3 HP vacuum pump through airtight tubes. The vacuum pressure was maintained between 25- and 30-inches Hg and the system was left to cure for 48 hours. The setup is shown in Fig. 1.

The cured composite laminates with a total thickness of 1.3 mm were removed from the vacuum bagging. Square shaped specimens of dimension 110 \( \times \) 110 mm were cut out from these cured laminates for electrical testing. The cutting operation was conducted by using an industrial shearing machine. The to be cut shapes of the specimen are as shown on the cured laminates in Fig. 2.

Out of the total nine specimens prepared, three specimens exhibited issues with lack of adhesion between the carbon fabric and the PET layer especially during the cutting operation. These specimens were discarded, and characterization was performed with only the remaining six good quality specimens. For the electrical measurements two strips of conductive copper tape were adhered to opposite sides of the specimens, spaced so that any interference with each other was eliminated, as shown in Fig. 3.

![Fig. 1. Setup used for fabricating the composite laminate specimens.](image1)

![Fig. 2. Specimens just after curing with the to be cut specimen shapes marked with chalk.](image2)
The specimens were then connected by means of copper connectors to a Philips PM6303A automatic LCR meter which measured their capacitance and resistance values. The measurements were taken by reading the specimen’s capacitance and resistance at 1 kHz, readily provided by the LCR meter. Both series and parallel measurements were conducted. The LCR meter also provided the capacitance density values. A sample measurement being taken, is shown in Fig. 4.

The measured data is shown in Table 1 for all six specimens. The average values and the standard deviation are shown as well.

Although there is some variation in the electrical properties, most specimens are seen to fall within the same range of values for all electrical properties. This consistency affirms that the fabrication procedure was repeatable. It is noted that the capacitance density values seen here are ~10 times lower than previously reported for similar material systems [1,2] but fabricated using pre-preg layers.

Fig. 3. Specimens cut and taped, ready for electrical measurements.

Fig. 4. Experimental setup showing one of the specimens connected to the LCR meter.
Table 1
Table of measured electrical properties of all six specimens.

| Specimen | Cp (pF) | Rp (MOhm) | Cs (F) | Rs (Ohm) | Capacitance density (nF/m²) |
|----------|---------|-----------|--------|----------|----------------------------|
| 1        | 250     | 10        | 225    | 8        | 20.7                       |
| 2        | 200     | 33        | 190    | 25       | 16.5                       |
| 3        | 388     | 23        | 387    | 7.5      | 32.1                       |
| 4        | 338     | 27        | 338    | 13       | 27.9                       |
| 5        | 370     | 28        | 372    | 6.5      | 30.6                       |
| 6        | 425     | 3         | 417    | 51       | 35.1                       |
| Average  | 328.50  | 20.67     | 321.50 | 18.50    | 27.15                      |
| Standard deviation | 86.42 | 11.64     | 92.56  | 17.34    | 7.14                       |

Acknowledgments

Kedar Kirane gratefully acknowledges the financial support via the start-up package provided by the Mechanical Engineering Department at Stony Brook University. Acknowledgements are also due to Mr Anthony Olivo from the Electrical and Computer Engineering Department at the Stony Brook University for help with electrical measurements.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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